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REVIEWS AND ABSTRACTS

In this section of the N.A.A.S. Quarterly Review, it is intended to survey current research and experiment in agriculture, horticulture and the allied sciences applicable to the work of the National Agricultural Advisory Service. It will not be possible, of course, to cover more than a small part of this wide field in each issue.

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Gibberellins and Gibberellic Acid

J. B. E. PATTERSON

National Agricultural Advisory Service, South-West Region

H. G. WELLS suggested in one of his books that men and animals could be made to grow to gigantic size by eating food containing special ingredients. So far, such extremely marked effects have not been found in animals, but a group of chemical substances known as gibberellins has provoked much interest in laboratories during the past few years because of their power of producing rapid and unusual growth in plants. Some of these materials are now beginning to come on to the market for commercial use.

Origin and Development

Crops of rice all over the world are susceptible to attack by a soil-borne fungus *Gibberella fujikuroi*, which produces the unusual symptom of increasing the length of stems and leaves of infected plants, so that fields of rice may seem to have been sown with a mixture of tall and short varieties.

In 1926 Kurosawa found that if cell-free filtrates from pure cultures of the fungus were sprayed in very low concentrations on to rice seedlings the characteristic symptoms of elongation were produced, and further work showed that many other species of plants responded in the same way.

The first crystalline material separated from the crude culture medium in 1939 was given the name of Gibberellin A. During the war and the years immediately afterwards investigations were continued in Japan, and it was found that Gibberellin A and another compound named Gibberellin B were both mixtures of active substances. Since the late 1940s research has been stimulated in Great Britain and the U.S.A., and in 1953—almost simultaneously in the two countries—a pure substance, known as gibberellic acid, was isolated and its chemical structure determined. Once this stage has been reached, the possibility of synthesizing any chemical substance would make likely the production of a reasonable quantity of material for investigation and practical tests, which if successful could probably lead to comparatively cheap production on a commercial scale.

Properties

Gibberellic acid and the gibberellins form an addition to the class of compounds which regulate growth—the plant growth hormones—and of these the auxins, such as indolylacetic acid and β naphthalene-acetic acid which affect cell-division and extension, have been used in everyday nursery work for some time, as have the selective herbicides 2,4-D, MCPA and MCPB. The latter, however, were developed because they have the additional property of stimulating extra growth,

which by its abnormality and distortion leads to death of the plant. Gibberellic acid, on the other hand, stimulates extra growth which is normal and may produce giant plants. So far no natural plant hormones with the physiological properties of gibberellic acid are known, and it seems odd that a material produced by, as far as we know, one single species of fungus should induce changes in plant metabolism, most of which can be brought about by alterations in light and temperature conditions.

There is, however, some evidence that naturally occurring materials similar to, if not identical with, gibberellins exist in plants. An extract of recently fertilized bean seeds, especially when made seven days after pollination, has been found when applied to bean seedlings to increase growth of all internodes, even if applied only to the first, and to cause earlier flowering and reverse the light inhibition of growth. Auxin does not produce these effects. A very active substance has been extracted from wild cucumber seed which will promote growth of dwarf maize mutants. Paper chromatography has also shown that beans produce a substance which behaves similarly to known gibberellins.

Effects on Plant Growth

The response to gibberellic acid may take various forms according to the type of plant. The most striking and typical effect is stem elongation, which may be as much as 150 per cent of the normal. It is generally limited to younger tissues which are still growing, and may result in a change of habit, as when a dwarf variety of garden pea (var. Meteor) is changed into a tall variety. In the process, the final height may be increased by 50 per cent, but the plant will have the same number of internodes as the ordinary dwarf plant, so that the gibberellic acid has increased the size of the plant cells (and thus the internode length) but not their number. In bushy dwarf sweet peas of the "Cupid" type treatment suppresses the growth of side shoots, and alters the leaflets in appearance from dark green ovate to pale green lanceolate, while almost doubling their surface area.

The quantity of material needed to produce a visible effect is very small—0.01 microgram (1 microgram = one millionth of a gram) but a single dose gives only a temporary response. To produce a steady increase in growth rate throughout a plant's life, regular applications of gibberellic acid of about one microgram per week must be made at fairly short intervals. Not only is the length of shoots increased, but often their fresh and dry weight, and it is suggested that this is a result of increased leaf area.

So far no instances have been found where gibberellic acid has stimulated root growth. Indeed, at fairly high concentrations it is inhibited. This suggests that growth regulation in roots and shoots differs in some way. One effect is to alter the relative proportions of root and shoot in plants suffering from nutrient deficiencies.

Increased Grass Yields

Wheat treated in the spring grows more rapidly at first, but no higher yields of grain or straw have so far been obtained. There is a danger that great increases in straw length of cereals may make the crop liable to lodging because of lower mechanical strength. On the other hand, interesting responses have been obtained from spraying grass swards with 2 oz per acre of gibberellic acid and cutting 4-10 weeks later. The dry matter yield was increased by between 2 and 8 cwt per acre, or 14-46 per cent, and although the percentage of protein was less than that of untreated grass this represents a worthwhile increase in protein per acre. However, a second cut without further treatment gave a decrease in dry matter of between 0.5 and 10 cwt per acre or 11-25 per cent.

If nitrogen is given at the same time in the ratio of between 320 : 1 and 640 : 1 an even greater effect can be produced. Gibberellins alone or with fertilizer encourage growth under conditions of low light intensity and low temperature. The practical possibilities, therefore, seem to be the promotion of early bite in northern latitudes or perhaps the extension of the growing season in the autumn or early winter. The Poa species are most responsive, followed by Agrostis and fescues, but ryegrass species are only slightly affected. This use of gibberellins on grass has recently been patented in Australia.

Earlier Fruiting and Flowering

With rice crops it was soon noticed that affected plants fruited earlier than the remainder of the crop, and it has been found that this effect occurs with many species of plants. Flowering in biennials, such as carrots, parsnips, sugar beet and some varieties of brassicas will not take place unless the plant experiences a short spell of low temperature whose critical value varies with each species. Ordinarily this happens in normal winters, and the long stem appears in the following spring. Full growth of this stem and production of flowers often depends further on the length of day. Moderate doses of gibberellic acid (about 60 micrograms) will induce stem growth even in the first season of a biennial at temperatures well above the critical value, and the effect of the dose is greatly increased if the plant is kept under long-day conditions. Still larger doses will overcome the effect of short-day conditions. In work with common henbane (*Hyoscyamus niger*) plants treated with gibberellic acid in long days flowered normally, but those kept under short-day conditions produced only a stem with no flowering. Thus the acid can act as a substitute for cold treatment but not for the long-day conditions.

Only a few plants in general commercial use have been examined for their response to this effect of gibberellic acid, but broccoli can be induced to head up in the field or under glass 10-15 days earlier. Among flowers, stocks given 5, 10 or 20 micrograms per plant will

flower between two and five weeks earlier, and varieties which normally need night temperatures lower than 60°F for flowering will produce longer spikes when kept at above that temperature.

Treatment of annuals results in earlier flowering for seed production; indeed, this has been induced up to 30 days earlier than usual in lettuce by repeated applications of 5-20 micrograms to the growing tip applied three times at fortnightly intervals.

Breaking Dormancy

Dormancy of seed and tubers can be broken by soaking them in a solution of 20-25 p.p.m. gibberellic acid in water. Lettuce seed needs red light for germination, but gibberellic acid can cause germination in spite of the fact that its effect on shoot growth is the opposite to that of red light. Dormant potato tubers will sprout if they are soaked in an aqueous solution containing 25 p.p.m. of gibberellins for 1½ hours, and epicotyl dormancy in apples can be overcome in the same way. It has been suggested that such treatment could take the place of "stratification" of seeds of ornamental shrubs and forest trees.

In many plants—notably cereals—gibberellins reduce fruit setting and yields to the extent of 32 per cent, but in one crop at least the opposite effect has been found. For parthenocarpy of tomatoes, gibberellin has been found to be 500 times more effective than indoleacetic acid.

Several methods of application have been tried:

(*a*) as a spray on foliage;
(*b*) by placing droplets of solutions on growing points of plants;
(*c*) by root adsorption;
(*d*) as seed treatments;
(*e*) as a paste on the stem.

The range of concentrations used is very wide—from 2 to 1,000 p.p.m in solution or from 5 to 100 micrograms per plant. Obviously much more detailed work will have to be done before recommendations can be made for everyday commercial use.

Experiments to Date

The present stage is that tests have been made on a wide range of plants in order to see which respond and in what way, and there is information about the following:

Flowers—stocks, petunia, annual larkspur, pansy, foxglove, forget-me-not, China aster, daisy (*Bellis perennis*) and Gerbera. These were treated with either 20 micrograms applied to stem apices or a foliar spray of 10-100 p.p.m. without excessive stem lengthening or detriment to market quality resulting. Dosage at higher rates produced over-long and weak stems, except in foxglove which can stand up to 600 micrograms.

Early flowering of vegetables for seeding—carrot, lettuce, endive,

mustard, spinach and radish. The dosage of these crops seems to be 20-100 micrograms or a single foliar spray of 100-1,000 p.p.m. The first four crops need repeated treatments.

Biennials for flowering preceded by marked elongation of stems—carrots, cabbage, kale, turnip, collards, beet and celery. Of these the most promising commercially is celery with which significant increases in fresh weight and dry matter of up to 50 per cent have been obtained.

Earlier market maturity—Beans (*Phaseolus*), and Broccoli.

Fruit setting—tomatoes, cucumber and eggplant.

Breaking of dormancy—potatoes, seeds of ornamentals.

Early growth—grass.

The metabolic effects of gibberellins have received much attention. The total dry weight of plants is usually increased, partly by redistribution of material from roots to shoots. The increase is caused largely by more carbon fixation, and carbon changes chiefly involve carbohydrates with reduction in starch content. One important fact is that the effect of gibberellins on carbon fixation is not directly related to photosynthesis.

Some work had been done on plant respiration changes, but so far without definite conclusions.

Of a wide variety of compounds tested, only L-tryptophan increased the growth response to gibberellin. If pea sections are kept for 18 hours in distilled water they lose their sensitivity to gibberellin while retaining it to auxins, but addition of tryptophan will partly restore it. There seems to be an auxin-gibberellin synergistic effect with starved tissue, and it is suggested that gibberellin promotes the conversion of tryptophan to the auxin indolyl-acetic acid.

Future Prospects

The practical value of gibberellins will no doubt be worked out in the next year or two now that larger quantities are available for experiment and some is reaching the retail market. The most obvious use is to develop grass production and to induce flowering and seeding, but it may well be that using them for increasing carbohydrate and cellulose materials will develop quickly. In forest trees, encouragement of rapid early growth of a straight unbranched trunk is very desirable, and for production of extra long fibres by the suppressive effect on branching, gibberellins could be valuable with flax, hemp, sisal and jute.

Something is known of undesirable characteristics, but more work is necessary to decide whether treatment of edible plants may have toxic effects.

Proper use of these new materials should yield exciting results in the next few years.

The Cost of Using Insecticides to Maintain the Health of Potato Seed in England and Wales

L. BROADBENT and P. E. BURT, *Rothamsted Experimental Station, Harpenden, Herts.*, and J. S. NIX, *Farm Economics Branch, School of Agriculture, Cambridge*

ABOUT 60 PER CENT of the potato acreage in England and Wales is planted with certified seed, and most of the remainder with once-grown seed. As about one-tenth only of the certified seed is produced in England and Wales, at least half the potato acreage is planted with seed imported from Scotland and Ireland. This is to avoid losses from leaf roll and severe mosaic (Y), the two aphid-transmitted viruses that cause "degeneration" in potato stocks, and is highly successful, except that the total cost amounts to several millions of pounds per year, and losses of tubers during transport are sometimes considerable. Another disadvantage is that the ware grower does not have his seed potatoes to store as he would wish through the winter or to plant at the best time. Many growers would therefore welcome an alternative method of obtaining healthy seed stocks, provided the cost were not greater than that now incurred.

Experiments were therefore started at Rothamsted Experimental Station to see whether the spread of leaf roll and Y viruses could be checked by spraying potato crops with various insecticides [2]. Considerable success was achieved, particularly against leaf roll, which is the more important disease, and as a result, the method has been tried more extensively under commercial conditions to get further information about its cost and practicability.

Many insecticides have proved effective in controlling aphids and checking the spread of virus, and DDT formulated as an emulsion—the cheapest and one of the safest tested—is used most widely at present. These tests were made with high-volume machines with overhead nozzles and underleaf lances, but recent work shows that low-volume application (about 25 gal/acre) of DDT with the same nozzle arrangement might be equally effective.

Quantity of insecticide and the time it is applied are very important. In the first experiments, six or more sprayings were made at fortnightly intervals, but it now seems that four or five may be nearly as effective. Spraying should start early, soon after the plants emerge, for at that time infected plants are more dangerous sources of virus than later, and the healthy plants are most susceptible. Two pounds of DDT (active ingredient) per acre per application are needed when the plants are growing quickly, but later sprayings need only 1 lb.

Results of many experiments suggest that aphid control will limit the spread of viruses only from infected to healthy plants within the crop. The insecticide does not kill aphids quickly enough to prevent those coming into the crop already infective from infecting some plants before they die. Millions of aphids per acre may leave potato crops in late July or early August in the south and east of Britain, and if the crop contained infected plants, some of these aphids will carry virus and may introduce it into other potato crops.

Two important conclusions may be drawn from these observations:

1. There is no point in spraying a healthy crop, because the insecticide will not prevent virus introduction, and the evidence to date suggests that there is little subsequent spread from plants infected in the same season;
2. Potato stocks could be maintained much longer if all growers would prevent the development of large aphid populations on all potato crops, except those planted with healthy Stock Seed, by spraying once or twice in early July.

Some growers are now doing (2) by including insecticides in their anti-blight sprays. Some maintain that copper toxicity from these sprays is severe when aphid feeding punctures are numerous, and an insecticide also decreases this trouble. Plant damage by spraying machinery is discussed later.

It follows from (1) that spraying could be stopped after the crop from which seed was to be saved had been adequately rogued, i.e., all diseased plants had been removed. This method—two or three sprays early in the season until roguing is completed—is now being tested on a farm scale.

Seed-potato Production

There are two methods of producing seed potatoes: either by saving the smaller tubers from the ware crops, or by growing an area specially for seed, when the crop will be close-spaced and may be lifted early—operations which usually result in less virus disease in the progeny. With either method the area of crop from which seed is to be saved should be rogued.

The costs of producing seed by these two methods are compared below with the cost of buying new seed. To make this comparison, several assumptions must be made about yields, costs and ware prices, for these can vary considerably from farm to farm and from year to year. In 1955 prices were exceptionally high; in 1956 they were very much lower. The figures given below are thought to be reasonable averages; current prices can be substituted where they differ substantially from those assumed. The assumptions are:

1. *Normal seed rate:* 19 cwt/acre for certified seed and 17 cwt for once or more grown [1].

   Seed rate for seed production: 30 cwt/acre.

2. *Average yield per acre from ware crops:* 8 tons of ware, and 1 ton of chats. Of this, 2 tons of small ware and ½ ton of large chats would be suitable for use as seed.

The 2½ tons of seed would plant roughly 3 acres at 17 cwt/acre, so that seed would have to be saved from one-third of the potato acreage.

3. *Average yield per acre from a crop grown for seed:* 8 tons of ware and seed (all re-planted as seed), and one ton of small chats.

The eight tons would plant nine acres, so that one-tenth of the total potato acreage would have to be devoted to seed production if fresh imported seed were grown on the seed area each year, and one-ninth if home-grown seed were used on this as well as the ware acreage.

4. *Prices:* stock seed: £26 per ton (including transport)
"A" seed: £24 per ton (including transport)*
ware: £12 per ton
chats: £3 per ton

5. *Cost of insecticide per acre per application:* £1 10s. (DDT emulsion).

6. *Roguing*. This is not difficult, and many farm workers could be trained to recognize plants with leaf roll or severe mosaic. The amount of roguing done per day depends on the incidence of disease and the energy of the worker: we have assumed about 2½ acres per man per day. The whole plant, including tubers, should be removed and destroyed.

Only the extra costs involved in growing seed potatoes, roguing and spraying, together with the receipts forgone by saving instead of selling the potatoes kept for seed, are considered in the calculations. This represents the "real cost" and allows for the drop in receipts as well as the costs of producing seed. Cultivating, manuring and harvesting costs are unlikely to be very different whether seed is saved or not. Small differences in the quantity of regular labour employed would in any case hardly affect total farm expenditure.

Seed as a By-product of the Normal Ware Crop

After the first year, the two-thirds of the ware acreage from which seed will not be saved should be sprayed at least once in July to kill the aphids before they become very numerous and fly to other crops. Such a spray should also be applied in the first year if any disease is seen in the crops.

The cost of seed when saving it from one-third of the ware acreage will be:

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*For simplicity, "H" seed is not included in the calculations, for a comparatively small acreage is now planted with this; its price is only about 10s. per ton less than "A" seed.

Items and Operations	Cost per acre over whole acreage £ s.	£ s.	£ s.
1st year			
Cost of seed: 19 cwt/acre of "A" seed (£22 16s. per acre) on ⅔rds of the acreage		15 4	
Cost of seed: 19 cwt/acre of Stock Seed (£24 14s. per acre) on ⅓rd of the acreage . . .		8 5	23 9
Subsequent years except the last			
Receipts forgone by saving part of the crop: 2 tons of ware @ £12 plus ½ ton of chats @ £3=£25 10s. on ⅓rd of the acreage		8 10	
Spraying ⅓rd of the acreage 5 times: Insecticide, £1 10s. per time	7 10		
Application costs: tractor and sprayer wear and tear, etc., 3s. per time	15		
	8 5	2 15	
Spraying ⅔rds once as above	1 13	1 2	
			12 7
Last year			
Receipts forgone (as above)		8 10	
Spraying whole acreage once		1 13	
			10 3

If the alternative mentioned above, of roguing and spraying three times (instead of spraying five times) were adopted, the costs on one-third of the acreage in the second and subsequent years would be:

	£ s.
Insecticide, 3 times @ £1 10s.	4 10
Application costs: tractor and sprayer wear and tear, etc., 3s. per time	9
Roguing, 2½ acres/man/day	12
	£5 11

The cost is therefore £2 14s. per acre less than spraying five times and not roguing (£8 5s. per acre), a decrease of 18s. over the whole acreage.

It is likely that spraying and roguing would allow the seed to be kept for three or more years in many areas. If it could be kept for four years, the cost per acre would be £8 to £9 per year less than that of buying "A" seed every year. It would also be about £2 per year cheaper than buying new seed every two years, which is common practice in some districts. The seed cost per acre of these alternatives, over a four-year period, are summarized below. Allowance is made for spraying all home-grown stocks once in their final year, even the once-grown stocks, to prevent numerous aphids developing on them and taking virus to healthy stocks on the same or other farms.

	"A" Seed every year not sprayed	"A" Seed every 2 years	Stock Seed every four years, sprayed 5 times in 2nd and 3rd year	Stock Seed every four years, sprayed 3 times and rogued in 2nd and 3rd year
	£ s.	£ s.	£ s.	£ s.
First year	22 16	22 16	23 9	23 9
Second year	22 16	10 3	12 7	11 9
Third year	22 16	22 16	12 7	11 9
Fourth year	22 16	10 3	10 3	10 3
Cost per acre per year	22 16	16 10	14 12	14 3

Seed Grown on a Special Area

Some growers will favour the alternative of devoting a small part of the total potato acreage to seed production. Early potatoes often sell for more than the cost of new seed, but in spite of this some growers save seed from the ware crop because once-grown seed usually gives an earlier crop than new; the special seed plot might appeal particularly to them because it could be on land that is not suitable for growing an early crop. The costs per acre are:

Items and Operations	Cost per acre over whole acreage £ s.	£ s.
First year		
Cost of seed: 19 cwt/acre of "A" seed (£22 16s. per acre) on 8/9ths of the acreage	20 5	
Cost of seed: 30 cwt/acre of Stock Seed (£39 per acre) on 1/9th of the acreage	4 7	
		24 12
Subsequent years except the last		
Receipts forgone (8 ton/acre of ware @ £12, plus 1 ton of chats @ £3)=£99: on 1/9th of the acreage . .	11 0	
Spraying 5 times: £8 5s. on 1/9th of the acreage . .	18	
Spraying 8/9ths of the acreage once	1 9	
		13 7
Last year		
Receipts forgone (as above)	11 0	
Spraying whole acreage once	1 13	
		12 13
Cost per acre per year over a four-year period . . .		16 0

An alternative method which would be slightly more expensive but would save spraying would be to plant one-tenth of the potato acreage with Stock Seed every year to produce seed for the following year's crop. The cost of this in the first year would be £22 16s. per acre (19 cwt of "A" seed) on nine-tenths of the acreage, and £39 (30 cwt of Stock Seed) on one-tenth, or £24 8s. overall. After this the "real

cost" would be £99 (receipts forgone) plus £39 (cost of Stock Seed) divided by 10 acres=£138÷10=£13 16s. In addition, there would be the cost of spraying nine-tenths of the acreage, at £1 13s. per acre, spread over the whole acreage: £1 10s. Total £15 6s. per year.

Over a four-year period then, the cost of this method would be £17 12s. per acre per year.

Which Method to Adopt?

The relative seed costs per acre per year, over a four-year period, of all the alternatives considered above, and in addition the use of Stock Seed every year and every two years, are shown below:

	£	s.
1. Buying Stock Seed every year for the whole acreage (no spraying)	24	14
2. Buying "A" Seed every year for the whole acreage (no spraying)	22	16
3. Buying Stock Seed every two years for the whole acreage (sprayed once in second year)	17	9
4. Buying "A" Seed every two years for the whole acreage (sprayed once in second year)	16	10
5. Saving seed from part (about a third) of the ware acreage every year. Spraying this area five times and the rest once, after the first year.	14	12
6. Ditto—but spraying three times and roguing after first year	14	3
7. Saving seed from a small special seed area every year. Buying Stock Seed for this area every four years. Spraying five times and the ware acreage once after first year	16	0
8. Ditto—but spraying three times and roguing after first year	15	17
9. Ditto—but using Stock Seed for the special seed area every year. Spraying the ware acreage once	17	12

Provided the stock can be kept vigorous for four years by spraying and roguing, savings of between £8 and £11 per acre can be made by growing home-grown seed instead of buying new "A" or Stock Seed every year. Between £400 and £550 per year could be saved on 50 acres of potatoes. Growing a small area specially for seed appears to be more expensive than retaining seed from part of the ware acreage, but this will largely depend on the weight of seed obtained. Also, the higher the price of ware potatoes, the less attractive is this method.

Different assumptions concerning the prices of ware and seed potatoes would of course affect these figures, but since these prices move together, the relative position, and therefore the saving, is not greatly affected. Other things being equal, the higher the ware price and the smaller the gap between ware and seed prices, the smaller the saving obtained by growing one's own seed. This is what would be expected, but the figures below show that the differences are not as great as might be supposed. Two alternative sets of assumptions are made about ware and seed prices: alternative I assumes the ware price to be near the support price at the early part of the season: £10 per ton; alternative II assumes it to be at the high level ruling during much of the 1955-56 season: £20 per ton.

	Original Assumption	*Alternative Assumption I*	*Alternative Assumption II*
	£	£	£
Price of ware (per ton)	12	10	20
Price of "A" seed (per ton)	24	20	28
Price of Stock Seed (per ton)	26	22	30
Method		*Cost of Seed per acre*	
	£ s.	£ s.	£ s.
1. Stock Seed every year	24 14	20 18	28 10
2. "A" Seed every year	22 16	19 0	26 12
3. Stock Seed every two years	17 9	15 2	22 12
4. "A" Seed every two years	16 10	14 2	21 13
5. Seed saved from ⅓rd of ware acreage: spraying 5 times	14 12	12 18	20 8
6. Seed saved from ⅓rd of ware acreage: spraying 3 times and roguing	14 3	12 8	19 19
7. Special seed area: Stock Seed on this every 4th year. Spraying 5 times	16 0	13 12	22 15
8. Special seed area: Stock Seed on this every 4th year. Spraying 3 times and roguing	15 17	13 9	22 12
9. Special seed area: Stock Seed on this every year	17 12	14 18	24 0
Saving of Method 6 over 2	8 13	6 12	6 13
Saving of Method 8 over 2	6 19	5 11	4 0

Other factors might also be considered, but there is not yet enough information about them. The cost of the DDT is a relatively small part of the cost of seed production, but some farmers and contractors might prefer to use other, more expensive insecticides. These would tend to favour the small seed area. Experience may prove fewer DDT applications to be enough when properly timed, but there is no doubt that, whether sprays are applied at high or low volume, underleaf lances can sometimes greatly improve aphid control. The more expensive systemic insecticides might prove adequate if applied from above only. At present, however, they may not be applied to ware crops.

Machinery passing through the fully-grown crop causes considerable damage, and may reduce the yield; at Rothamsted six or eight passages of the spraying machinery reduced yield by about 10 cwt/acre during two years, but this was offset by the sprayed plants yielding better than the unsprayed, probably because they suffered less direct insect injury. The possibility of damage is an argument for growing a special seed area; also, between periods of bad weather it is easier to spray a small acreage than a large one. Damage could be minimized if British farmers used haulm-dividers on their machines, as used by potato-growers in the U.S.A. Further, if the area from which seed is to be saved is rogued adequately, and spraying is stopped when the roguing is completed in early July, little damage is done. In any event, if the

later sprays were applied at the same time as anti-blight sprays, no additional damage would be caused.

The savings in cost that we have estimated do not take into account the earlier maturity (especially of early varieties) often obtained with healthy home-grown seed, in contrast to imported seed, which may be damaged in transit and cannot always be so well sprouted before planting.

These experiments have been made at a time when the health of British potato stocks is higher than ever before because of the success of the certification schemes. In other countries where the general health of potatoes is lower, they have been less successful. Before any change is made from the old, well-established method of buying new seed from Scotland and Ireland at frequent intervals, care must be taken to prevent the general health of our potato crops from deteriorating, which might happen if aphids were allowed to breed on partially-infected older stocks and carry virus to the new ones. This is the limiting factor in any scheme for seed production in England and Wales at present, for although leaf roll presents no problem, it is impossible to stop completely the spread of virus Y once it has been introduced into a stock. We cannot expect all farmers to co-operate by spraying all ware crops containing diseased plants, so individual farmers who would like to keep their own seed should experiment on a small acreage for a few years to find out if it is feasible in their locality. In general, the greater the separation from other potato crops that can be achieved, the more likely is the effort to succeed.

It cannot be stressed too strongly that it is useless to attempt this method of seed retention unless the work is done properly. It might even be dangerous, for should virus diseases again become prevalent because of inefficient spraying, their control even by efficient spraying will be difficult.

This is work in the *development* stage, and further experience and information are desirable before advisers can recommend the methods for general application. Consequently, N.A.A.S. officers should keep in close touch with, and be prepared to give special advice to, farmers contemplating work on the lines described, so that the maximum amount of information may be obtained on these pioneer efforts.

Summary

The useful life of potato seed stocks in the south and east of Britain can be prolonged by spraying with insecticides which check the spread of aphid-borne viruses. Spread of leaf roll virus from infected to healthy plants within a crop is the main cause of stocks degenerating and this can be almost entirely prevented. Spraying healthy stocks will not prevent viruses being brought into them from other potato crops, but the few plants that become infected in this manner can be removed. This spread between crops could probably be prevented by spraying all crops.

Spraying and roguing to maintain the health of a potato stock costs £8 to £11 per acre less per year than planting new "A" or Stock Seed, but the difference in cost depends on the method adopted and current market prices. The cheapest method is to spray and rogue part of the ware crop and save seed from this, but there may sometimes be advantages to offset the slightly greater cost of growing a crop specially for seed.

References

1. D. A. Boyd and W. J. Lessells. The effect of seed rate on the yield of potatoes. *J. agric. Sci.*, 1954, **44**, 465-76.
2. L. Broadbent, P. E. Burt and G. D. Heathcote. The control of potato virus diseases by insecticides. *Ann. appl. Biol.*, 1956, **44**, 256-73.

Induced Mutations and Plant Breeding

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UNTIL 1927, plant breeders and geneticists had to make do with whatever variability existed in their material or arose spontaneously during the course of their work. In view of the apparently inexhaustible variability of living organisms, this may not appear a severe restriction. In fact, nobody could confidently set limits to the advances possible, by using the time-honoured methods of selection and hybridization, to adapt crop plants to the constantly improving environments provided by developments in farming methods. Nevertheless, the idea of not merely utilizing hereditary differences, but actually producing them and even of controlling the kinds of variants produced has obvious attractions. In 1927, both Muller, working with the fly *Drosophila*, and Stadler, working with cereals, discovered independently that the frequency with which hereditary changes (mutations) occurred could be greatly increased by irradiation with X-rays.

The discovery opened up a whole new field of biological research, interest in which has more recently been re-stimulated by developments in the field of atomic energy; nuclear fission and radio-active decay are both accompanied by the production of radiations which also induce mutations. The purpose of this article is to give a very brief account of some of the more fundamental aspects of induced mutations and to consider their possible uses in plant breeding.

Promoting Molecular Disorder

The process by which chromosomes are exactly reproduced must obviously be a very orderly one, and it is reasonable to suppose that any influence tending to promote disorder might lead to errors in the copying process. The simplest way to promote disorder at the molecular level is to raise the temperature, and it has been demonstrated several times that there is a detectable increase in the frequency of mutations at higher temperatures. But the practical utility of heat treatment for inducing mutations is severely limited by the relatively low maximum temperatures tolerated by living organisms. Some other method of conveying excess energy to the molecules of the chromosomes may be considered next. The spectrum of electromagnetic radiations ranges from low frequency or long wavelength radio waves, through infra-red, visible light and ultra-violet to X-rays and gamma-rays. It is well known that the energy they transmit is not infinitely divisible but is made up of "quanta", the quantum of energy being proportional to the frequency. Ultra-violet radiation has the lowest frequency which yields sufficient energy per quantum to bring about a useful increase in the production of mutations. Because of its low penetration it can only be used in practice on unicellular organisms or on unicellular stages of higher organisms, e.g., pollen grains. Its main interest is perhaps its property of inducing only point mutations, that is changes of one Mendelian factor, not accompanied by any gross structural changes in the chromosomes. X-rays and gamma-rays do, of course, penetrate living tissue, and in doing so they transmit sufficient energy to molecules to knock electrons right out of them, leaving the molecule with a positive charge and therefore transformed into an ion. This process of ionization may affect the molecules of genetically important parts of the chromosome so as to produce a genetic change, referred to as a direct effect. Indirect effects are supposed to occur when ions, produced outside the chromosomes, start a chain of reactions which end in the chromosome to give genetic changes. The distinction between direct and indirect effects is usually difficult to draw but can be demonstrated in the microbiological field. The occurrence of indirect effects is a possible explanation of the fact that the yield of mutations depends on the conditions under which the material is irradiated.

Biological effects of X-rays and gamma-rays comprise point mutations, gross structural alterations of the chromosomes and general damage to the cells. There is abundant evidence to show that point mutations result from single ionizations. Most of them are recessive and are brought to light by a process of inbreeding. In plant breeding studies with X-rays the dosages used are heavy (thousands of roentgen units) and the resulting cytological damage which necessarily accompanies the induction of point mutations means that many of the latter are lost, through deaths in the treated generation, sterility of treated individuals, or abortion of embryos at an early stage in the next genera-

tion. Most of the point mutations which do come to light are recessive lethals, causing premature death of any individual which is homozygous for them; many of them are chlorophyll-deficients of one kind or another. Most of the non-lethal mutants are freaks of no agricultural interest at all, but there is a residuum of mutants within the normal range of viability and fertility and having features of agricultural interest.

As an example of the class of potentially useful mutants, the *erectoides* type occurring in barley may be cited. They are distinguished by shorter straw and denser ears than the variety in which they arise; about a score of them have been produced in the course of some very intensive studies on induced mutations in barley by Swedish workers. Their agricultural interest lies, of course, in their resistance to lodging; some of them are earlier than the parent variety and though they are mostly lower in yield, at least one is claimed to out-yield the parent variety when heavy applications of nitrogen are given. Small-scale trials of *erectoides* mutants have been in progress for ten years or so and some have reached the stage of larger-scale regional trials, but so far none has been marketed. This may be because barley improvement has made good progress during the same period by the ordinary methods of hybridization and selection, but whatever the reason, the example serves to show that there is a long row to hoe between the discovery of a useful looking mutant and its emergence as a commercially valuable variety. Hence the cautious reserve which many plant breeders maintain towards enthusiastic claims about induced mutations.

In the writer's opinion, it is still too early to judge the value of induced mutations in plant breeding. So far as the present evidence goes, it would still be possible for either the almost unbridled enthusiasm of some workers or the extreme scepticism of others to prove justified. All that can be said is that the aim of gaining some control over variability at its source will undoubtedly continue to attract workers into this field and rather than speculate on the prospects of success, it may be more profitable to consider possible lines along which the work might develop.

Elaboration of Selection Procedures

One line along which development is already proceeding is the elaboration of selection procedures to facilitate the recognition and isolation of very rare variants. Here work with induced mutations overlaps with work which differs only in degree from normal plant breeding work. For instance, the original selection work which led in prewar Germany to the creation of sweet lupins, involved testing about a million-and-a-half individuals for low alkaloid content. Only five (three yellow lupins and two blue) were found. They formed the starting point for what was virtually a new crop. Although in this case

nothing had been done to increase the rate of mutation, it is clear that techniques allowing selection on this scale are likely to be needed by anyone working on induced mutations. They can only be applied where a specific objective is clearly defined and then only when the desired type can be easily recognized. An obvious and by no means unimportant field, in which such methods can be applied, is that of disease resistance. Similar cases arise when attempts are made to extend the geographical limits of a crop. For example, with heat-loving crops like soya beans or maize in northern temperate zones, one would like to sow earlier to make the best use of the warmest summer months. Here the difficulty is that the existing forms will not germinate at a low enough temperature. If mutations can be induced which confer a lower minimum germination temperature, it should be a simple enough matter to recognize, and isolate them. Work on these lines with soya beans is already in progress in Germany.

In some instances it may be impossible to achieve the desired objective in one jump. Another possible line of development is therefore to put the material through cycles of treatment and selection. Alternatively, selection and treatment might proceed together. Here the method of "chronic" irradiation is of interest. This consists of growing plants in an isolated field in the presence of a steady source of ionizing radiation, usually gamma-rays from radio-active cobalt.

Most of the work on radiation-induced mutations has been done so far on seed-propagated, self-pollinated crops; technically, seeds are very convenient for irradiation and with self-pollinated crops it is easy to obtain genetically pure starting material. What then, are the prospects of application to other types of crop? Cross-pollinating crops normally carry a fairly heavy load of recessives, which only come to light on inbreeding, and so the distinction between induced and natural mutations is largely a matter of statistics, unless inbred material is already available. If a cross-pollinated crop is diploid or allopolyploid, only one generation of inbreeding by self-fertilization is needed to produce homozygous mutants. If self-fertilization is very difficult, as in red clover, or if the crop is autotetraploid, like cocksfoot or lucerne, two generations of inbreeding would be needed. With timothy, which is most probably autohexaploid, three generations would be needed. It seems likely therefore that breeders of cross-pollinated crops, especially if they are autopolyploid, will turn to induced mutations only as a last resort. A possible instance is provided by verticillium wilt of lucerne, resistance to which may be very difficult to obtain in any other way.

With vegetatively-propagated crops, the convenience of seed for irradiation is offset by the fact that the good points of the variety may be lost with seed-propagation. Such crops are usually irradiated as growing plants, to increase the frequency of bud sports.

Chemically-induced Mutations

Turning now to longer term prospects, perhaps the most intriguing is the use of chemicals to induce mutations. A great many chemicals are now known to induce mutation, but from the purely quantitative point of view their value is limited by the fact that the mutation rates attainable are less than with ionizing radiations. The point of interest lies in the possibility of controlling the kinds of variant produced. A widely accepted working hypothesis is that the genetically important part of the chromosomes is desoxyribosenucleic acid (DNA) and that the order in which the purine and pyrimidine bases of DNA are arranged determines the sequence of amino-acids in proteins. If this hypothesis could be established, and if much more detailed biochemical knowledge of the processes involved could be obtained, then the possibility of controlling variability would be more likely. Only a few years ago one would have said that this prospect was very remote, but in that period work on the structure of both DNA and proteins has not only made giant strides, but has also moved much closer to genetics.

Finally, further techniques for inducing mutation may still be discovered or made more practicable by technical advances. Thus the use of gamma-rays at one time needed a radium source. With the atomic pile as a plentiful source of neutrons, artificial radio-activity became much easier to manage and cobalt-60 is now much cheaper than radium as a source of gamma-rays. Neutrons themselves have advantages over X-rays as ionizing radiations for the induction of mutations; but as long as they could only be obtained from a cyclotron this point was of largely theoretical interest. Another by-product of atomic energy work is the greater availability of chemical compounds incorporating radio-active isotopes ("tracers"). Such compounds can be used to introduce radio-activity inside the cells of plants. Using radio-phosphorus in this way, mutations have been induced. Phosphorus is an important constituent of DNA and there is evidence from work on bacteriophage that it is the decay of radio-phosphorus to sulphur which produces the change in the DNA, rather than the ionizing radiations which accompany the decay.

Work on the utilization of induced mutations in plant breeding is increasing and the rate of advance in cognate fields is enormous. While at present some caution is needed in considering the potentialities of induced mutations, in four or five years the picture may be very different.

Looking Back

Twenty-one years of Poultry Advisory Work

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RELUCTANT though we may be to admit it, we are all of us faced one day with the stark realization that we are middle-aged. My moment of awakening came when I was going through the cupboard and came upon a diary of 1936. Only then did I realize that I had been engaged on poultry advisory work for twenty-one years in Shropshire, and scanning the pages of this relic of the past my mind went back to conditions in those far-off days. I question whether any other branch of agriculture has progressed so rapidly or so far in the period as this erstwhile "Cinderella" of farming. It is not my intention to dwell on the poultry industry as we know it today, but I thought that for the enlightenment of younger members new to the service, some recollections of the past might be of interest.

Just twenty one years ago I came to Shropshire as a Poultry Instructress with the County Council. I had the National Diploma in Poultry Husbandry and eighteen months' experience at a Farm Institute in the north. With the brashness of youth I was convinced that I knew all there was to know about poultry husbandry. Now experience has taught me how much we have still to learn.

My salary on appointment was £160 per annum. I had a second-hand Austin 10 h.p. car supplied by my father, who also gave me £5 to start a banking account. Travelling expenses were on a flat rate of 4d. a mile and for 30s. a week I acquired excellent digs on a farm three miles out of town, where in due course I also kept a riding pony! Old cheque stubs show that I paid 17s. 6d. per half-year income tax. All this seems fantastic now, but in those days I was comparatively well off and saving money.

There were about ten of us on the staff—general agriculture, horticulture, dairying and poultry. Our offices were in an old building in the town and the poultry office was a tiny room at the top of the stairs affectionately known by all as "The Broody Coop". Here the late Mr. Crowther and myself carried out our office duties in a cubic air space which would be condemned in a modern deep litter poultry house.

Culling ad nauseam

Shropshire is essentially an agricultural county with a great proportion of the poultry population kept on general farms, and in 1936, poultry were often a source of pin money for the farmer's wife. The practice was for the farmer to pay for the food while his wife looked after the

hens and kept house on the proceeds. In many instances, if the farmer had given his wife money for their own food instead, it would have saved both her and myself a great deal of work by eliminating the poultry entirely, and have been much more profitable into the bargain!

Life at once became one long orgy of culling hens. Looking through my diary I see that I culled literally thousands of birds in that first year, and cases of B.W.D. cropped up with automatic regularity. There were few Accredited Breeders and it was the practice of many farmers to hatch their own replacements—usually in small hot-air machines—hence the routine of culling and blood testing which occupied most of my time in the early part of the year. It is now the practice for Animal Health Division of the Ministry to undertake the blood testing on Accredited farms, but in those days the breeders did their own by the old test tube method and, when time permitted, we often spent a full day on one farm helping to take blood samples.

The disease picture has altered beyond recognition. Looking at my records I find that along with B.W.D., coccidiosis and worm infestations were a constant source of trouble. Coccidiosis was treated with "Kerrs Iodine" and improved hygiene—we had none of the drugs available which are in general use today. Leucosis was unheard of though we had the odd case of Leukaemia, and Blackhead in turkeys was treated by injections with an arsenical preparation—sometimes effective, sometimes not. It was a case of survival of the fittest!

Mash Unlimited—and Wine

Intensive housing was rare. It was the era of "all dry mash feeding", a comparatively new labour-saving idea, and we were obsessed with the idea of getting a good mash hopper which would not waste food. It was no uncommon sight to go into the hen house and find the birds literally wading through dry mash on the floor. Mash incidentally was about 7s. per cwt.! This prodigal wastage of food may have been in some measure responsible for the heavy worm infestations we encountered.

As I mentioned earlier, poultry-keeping was the prerogative of the farmers' wives, a section of the public noted for their hospitality. Shropshire was a county famed for its home-made wines, and as a result one was frequently regaled with delicious home-made brews which I never had the strength of mind to refuse. Experience taught me, however, that many of these golden innocuous-tasting liquids could be deadly in their effect. While leaving the mind unclouded they could impart a paralyzing effect from the waist downwards. Cider brewed in the southern part of the county offered no temptation as it was of the rough variety and tasted (to me) like rusty iron filings. I have often watched with amazement, however, while young children of the household drank it with apparent enjoyment.

Local Shows and Lectures

We invariably had a stand at the West Midland and other small local shows in the county. No money was allocated for this purpose, and our efforts must have seemed very amateur. We painted all our own show cards and captions, and as I had some slight flair for the work my services were in great demand at these times. I have happy recollections of the small local shows. Often they incorporated a fair to which one could adjourn in the evening, and I remember one great attraction being motor racing in the show ring where any one could enter their car—one could buy a good second-hand one for £25. The excitement over these races was intense—more so than anything I have since encountered at Silverstone.

We gave lots of lectures in the winter. Women's Institutes were one of our most fruitful fields of endeavour as most farmers' wives were members of their local institute. Chicken rearing was a favourite subject and demonstrations on trussing and boning were always in great demand.

There was in the county a very flourishing Dairy Students' Association to whom we lectured on different aspects of poultry husbandry. The various branches also competed amongst themselves at the shows with butter-making and poultry trussing competitions.

Every year in the winter months each local branch held a social evening to which we were invited. The rivalry between them must have extended even to this social for we were regaled with the most magnificent suppers. I particularly recollect the luscious trifles thick with whipped cream which were always a speciality of these functions.

Classes for Younger Disciples

One of my outstanding memories however, is of the "Junior Agricultural Organized Courses" which we ran during the winter months. These were familiarly known as "JOC's", and consisted of classes of young members of the farming community varying in ages from about 12-21 years. They were invariably held in remote parts of the county and reached by us in our not very reliable cars under the most trying and difficult weather conditions. Attendances were remarkable as there were no counter attractions such as television, and the youth of those days was not as blasé as today. I think they must have been under some supervision from the education committee because I remember filling in a register and I think we set an examination paper at the conclusion of the course. It was customary for two members of the staff to go together and talk for three-quarters of an hour on his or her particular subject. Three or four nights per week were taken up by "Joc's" during the season, and the classes were usually held in the village school-room or institute heated by coke stoves which would glow red all over when stoked by some particularly enthusiastic caretaker.

Many of our younger and keener disciples came straight from their work in the cowsheds or stables, and as the heat increased, the

fumes from their corduroy trousers which were well impregnated with milk or F.Y.M., rose steadily and formed an atmosphere which I can vividly recall even to this day.

"The Old Order Changeth . . ."

Now all these girls and youths that I remember are staid married pillars of the farming community with teenage families of their own, a generation which will grow up familiar with the use of sulphonamides, antibiotics, hormones and tranquillizers. They too, will have their marketing and overproduction problems to solve but doubtless with a lot of new discoveries and new systems to help them on their way.

The "good old times"—all times when old are good—are gone.

Reviews and Abstracts

The Importance of Molybdenum in Agriculture, with Special Reference to British Conditions

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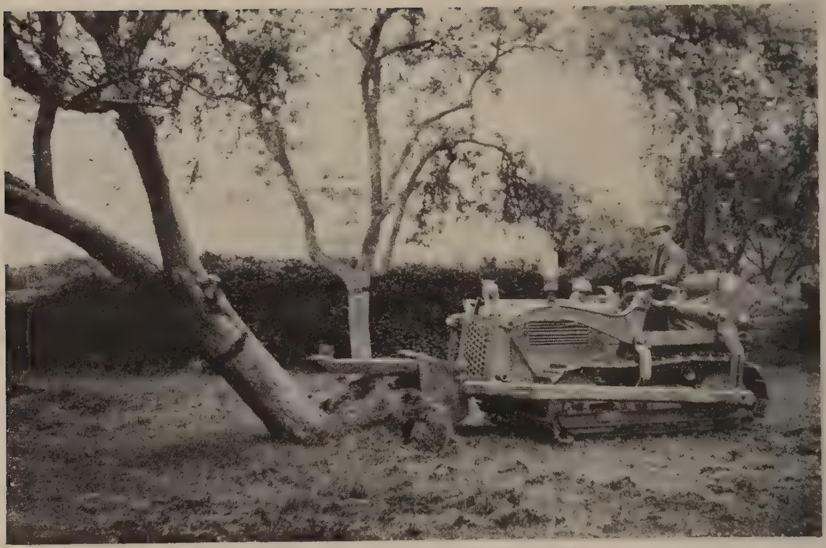
Introduction

THE EXISTENCE of symptoms and disorders which are now known to be associated with molybdenum has been known for a long time. Severe scouring in cattle when grazing on certain pastures, known as "teart" in Somerset, Gloucestershire and Warwickshire, is the best known toxic effect. This was first recorded in 1850. In 1855, Clarke's investigations showed that the teart lands were associated with the blue lias clays. Many investigations during the latter part of the last century and the earlier part of this, failed to trace the cause of the trouble. Osmond's work on the soil survey of Somerset 1934-37 showed a correlation between the teartness of the pastures and certain definite soil types derived from the Lower Lias either directly, or by alluvial deposition or by drift. The affected soils were neutral or alkaline in reaction and had highly calcareous grey or grey-blue clay near the surface. The actual cause was eventually discovered in 1936 by Ferguson, Lewis and Watson [22]. These workers used spectrographic methods for comparison of samples of soil and herbage from healthy and affected fields and they found that the herbage from the teart pastures contained much more molybdenum

THE GRUBBING OF OLD FARM ORCHARDS

(See pp.179-84)

PLATE I



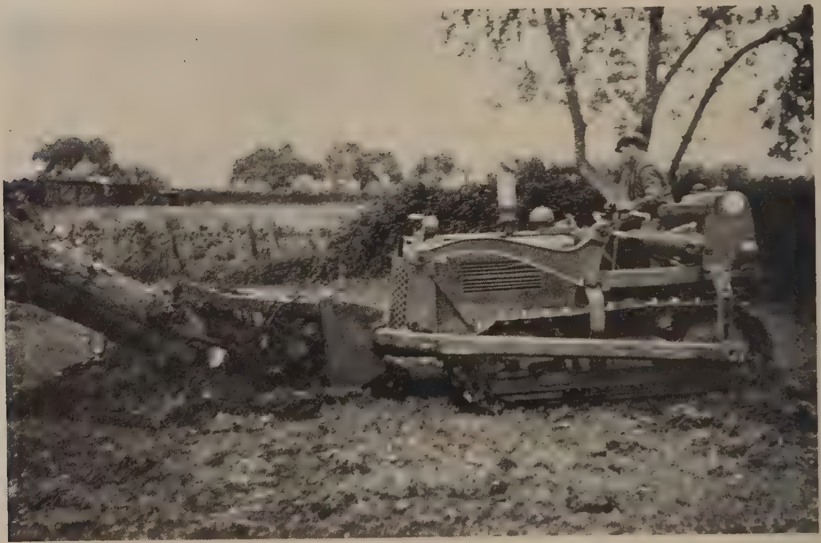


PLATE II

PLATE III

PLATE IV

than ordinary herbage. Normal herbage contains less than 5 p.p.m. of molybdenum in the dry matter whereas that of the teart pastures contains from 20 to 100 p.p.m.

Recognition of the role of molybdenum and its importance in plant growth is a very recent development in agricultural research. In 1939, Arnon and Stout [5] had shown that molybdenum was essential for the nutrition of the tomato plant, and in 1940 Piper [43] found this element to be necessary for grain formation in oats. The most spectacular symptom of its deficiency—"Whiptail"—has been known for some time and its earliest recognition in broccoli and cauliflower was made by Clayton [11] in New York State in 1924. During the next seventeen years, the disorder was further studied by several investigators. They did not discover its cause, but found that it could be cured by liming. However, it was only after molybdenum had been found to be essential for plant growth that Whiptail was finally shown to be due to molybdenum deficiency by Davies [13] and Mitchell [35] in 1945. In this country, Hewitt and Jones [27] also showed that Whiptail was due to a deficiency of molybdenum and further reports include those of Jones and Dermott [31] and Plant [46, 48 and 49]. These workers and others, mainly from Australia and New Zealand [53] have subsequently reported field responses to molybdenum by brassica crops.

Although Bortels [9] in 1937 reported responses to molybdenum on leguminous plants grown in sand culture, it was not until 1942, when Anderson [2] obtained responses to molybdenum on clovers in pastures that attention was drawn to this work. Anderson's work stimulated the interest of agricultural workers throughout the world in this problem, and within a few years soils responsive to molybdenum were found in a number of countries. Molybdenum deficiency has been identified in more than 40 crop plants including cabbage, rape, kale, swedes, turnips, celery, lucerne, oats and wheat [33 and 55]. Those most commonly affected under field conditions in this country are vegetable crops and legumes.

Role of Molybdenum in Plant and Animal Nutrition

It was shown by Bortels [8 and 9] in 1930 and subsequently confirmed by numerous other workers, that molybdenum is essential for nitrogen fixation by species of bacteria Aztobacter and Rhizobium [21]. More recently it has been shown that higher plants require molybdenum for the reduction of nitrates and the consequent build up of protein. Shortage of molybdenum results in the accumulation of nitrate in plant tissues [21]. Its function in this connection has been shown by Nicholas and Nason [41] as being the metal constituent of the plant enzyme "nitrate reductase". The Long Ashton workers [1 and 29] have also shown a significant decrease in the ascorbic acid content of molybdenum-deficient cauliflower plants and suggest that either molybdenum is

essential for the synthesis of this vitamin or that the accumulation of nitrate causes its destruction in the plant.

It is the toxic effect of molybdenum rather than its deficiency which is more important from the point of view of stock health. Copper sulphate has been found to be successful in counteracting this toxic effect of molybdenum in stock [22 and 23]. Its use was originally suggested by the similarity in the symptoms of scouring on teart pastures to those of the cattle grazing on the copper deficient, reclaimed land of the Zuider Zee. In 1945 Dick and Bull [18] demonstrated that molybdenum could exert a profound effect on the copper metabolism of ruminant animals.

Walsh, Neenan and O'Moore [57] reported in 1952 a condition occurring in livestock in several areas in Eire similar to that described elsewhere as conditioned copper deficiency. They found this to occur on pastures of moderately high molybdenum contents (5-25 p.p.m. Mo) as compared with the normal figures of 0.5-3.0 p.p.m. The copper content of the herbage and the blood copper of the animals were quite normal, yet dosing with copper salts was an effective control.

The relation between molybdenum and copper in animal metabolism has been investigated by Australian workers. Dick [17], during investigations on the effect of molybdenum on the copper metabolism of sheep found that the magnitude of the effect of molybdenum on the depletion of copper reserves in the animal was dependent on the inorganic sulphate content of the diet. These studies indicated that the depletion of copper reserves by molybdenum was greater with increased inorganic sulphate intake when the copper intake was normal. In 1955, Wynne and McClymont [62] reported that it was possible for the copper reserves of sheep to increase on comparatively low copper intakes if both the molybdenum and sulphate contents of the diet were low, and conversely, the copper reserves could be depleted to deficiency level in the presence of high molybdenum and sulphate, even though the copper intake may be high. On the other hand, Bull [10] had shown in 1949 that when sheep grazed pastures of very low molybdenum content (<0.1 p.p.m. Mo) an excessive accumulation of copper could take place in the liver which might produce chronic copper poisoning.

Although molybdenum has been found to be a co-factor in the flavoprotein enzyme, xanthine oxidase [16 and 43] studies have failed to demonstrate that it is an essential dietary item for the rat or any other species.

Molybdenum Content of Soils and Factors Affecting its Availability to Plants

A systematic survey of agricultural soils carried out in the United States and New Zealand [51, 52 and 58] indicated that 95 per cent of the samples contained from 0.6 to 3.5 p.p.m. of "total" molybdenum. Like other

plant nutrients, the total molybdenum content of soils, except at very low levels, gives very little indication of its availability to plants. Deficiencies have been observed in soils quite normal in total molybdenum content (0.8-3.5 p.p.m. Mo) e.g., ironstone soils in Holland [37]. Excesses have been reported by Walsh, Neenan and O'Moore [57] on mineral soils quite normal in total molybdenum content.

Excess molybdenum in soils has also been found in California, Oregon and Florida, and the vegetation growing thereon has been found to be toxic to cattle. In New Zealand, Cunningham [12] has surveyed pastures on all the main soil types and he lists a number of soils prone to give high molybdenum pastures.

Barshad [6] has suggested that the available molybdenum may be present in three forms in the soil, viz. soluble molybdate salts; molybdenum combined with organic matter; and as an exchangeable molybdate anion held by soil colloids. The most important factor, however, affecting its availability to plants is soil reaction, as it increases with increasing pH. Piper and Beckwith [45] demonstrated the greatly increased uptake of both applied and soil molybdenum with increasing pH on clover whilst in New Zealand, Davies [15] found a correlation between pH and response to molybdenum.

Oertel, Prescott and Stephens [42] studied, by pot experiments, the growth of subterranean clover in a shaley clay loam adjusted to varying pH values ranging from 3 to 10. In the presence of added molybdenum, yields rose rapidly up to a pH of 5.8 and did not alter on increasing the pH to 7.9. In the absence of molybdenum, these maximum yields were not obtained until the pH was 6.9. Field trials carried out on broccoli in Cornwall by Plant [46, 47, 48 and 49] showed that, on two soils of pH 4.8 and 5.2 respectively, 2 lb per acre of sodium molybdate was just as effective in reducing the incidence of whiptail as 3 tons per acre of ground limestone. A further reduction in the incidence of whiptail occurred when 4 lb sodium molybdate was applied and the deficiency was completely eliminated in the soil with a pH of 5.2. In another trial, carried out in the Gower peninsula on Old Red Sandstone drift soil of pH 4.8 Plant showed that 5 tons per acre of ground limestone and 4 lb per acre of ammonium molybdate were equally effective in reducing the incidence of whiptail. The molybdenum content of the leaves from the lime treatment was equal to that of the molybdate treatment, which was double the amount found on the control. At the toxicity level, Lewis [32] has shown that if the pH was below 7.0 on the teart soils of Somerset, pasture was non-toxic even though the soil might contain as much as 33 p.p.m. of total molybdenum.

It is quite evident from all these investigations that liming, with the consequent increase in pH, raises the availability of soil molybdenum,

and some Australian and American workers [20 and 30] have suggested that a well-limed soil may become depleted of its available molybdenum supply by losses through leaching and exhaustive cropping.

Field trials on pasture in Australia and New Zealand have shown that applications of from 2 to 3 oz per acre of sodium molybdate on molybdenum deficient soils were almost as effective in increasing growth as an application of 2 tons of ground limestone per acre. The relationship between molybdenum availability and lime status appears to be complicated. Anderson [3] states that on some soils, responses of plants to molybdenum do not occur if lime is applied; on others responses only occur when some lime has been applied and on still other soils lime may have little or no effect on the response to molybdenum. He quotes one case where quite small amounts of lime (2 cwt per acre of ground limestone drilled with the seed) induced clover nodulation and gave large responses in yield when molybdenum was applied whilst without this lime addition there was no response. In another case, because of the very low content of unavailable molybdenum (<1 p.p.m.), the response of clover to lime was very small compared with that given by molybdenum alone or molybdenum plus lime.

The effect of phosphate in increasing molybdenum uptake has been noted by several investigators [4, 7 and 54]. Mulder [38] has pointed out that on some phosphate deficient soils, less phosphate was required to give optimum growth of cauliflowers if molybdenum were present. The same worker has also found that a high iron content in soils decreases molybdenum availability by strong absorption.

Applications of fertilizers containing sulphates also appear to decrease the uptake of molybdenum in some acid soils [54]. In Eire, Walsh, Neenan and O'Moore [57] demonstrated that monocalcium phosphate had a greater effect than superphosphate in increasing molybdenum availability on acid soils which they account for by the presence of calcium sulphate in the superphosphate. On alkaline soils, however, sulphate does not affect molybdenum uptake [7].

Millikan [34] has shown that appreciable amounts of other heavy metals such as copper, manganese, nickel and zinc in the soil solution increases plant requirement for molybdenum.

Of the extractants suggested for assessing the availability of soil molybdenum, Tamm's acid oxalate (pH 3.3) [25] has been widely used in New Zealand by Grigg [24] and gives a useful correlation with response. Other New Zealand workers [14 and 15] found it of value in identifying molybdenum deficient areas when the amount extracted was considered in relation to the pH. At pH 5.0 the response level was 0.30 p.p.m. of extractable Mo whilst at pH 6.5 it was 0.05 p.p.m. In Eire [57], the method has also been used in comparing soils from areas with herbages of high and low molybdenum content. Figures varying from 0.2-0.7

p.p.m. of available molybdenum were obtained when excessive amounts of molybdenum were present in the herbage, and 0.06-0.12 p.p.m. where they were deficient.

The Aspergillus niger method is also widely used by workers in Great Britain, Australia, Holland and America [19, 26, 36, 40 and 56] for assessing the availability of soil molybdenum. Mulder [38] suggests that this method serves to distinguish between true molybdenum deficiency and that induced by deficiency of phosphate. He also states that, on some strongly acid soils in Holland, the high concentrations of available manganese in these soils inhibits the uptake of molybdenum by cauliflower but not that by Aspergillus niger. Grigg [24] has obtained good agreement on some Australian samples between oxalate soluble molybdenum and the Aspergillus niger method. In 1948, Piper and Beckwith [44] introduced a new method for the analysis of plant material for molybdenum, and Williams [60] has since modified the method to include soils.

Incidence and Control in Horticultural Crops

In England, this problem has been mainly investigated by research workers at Long Ashton. Plant [49] has found whiptail to occur on a wide range of acid soils derived from Granite, Devonian (Shale), Old Red Sandstone, Keuper and Lower Greensand. The parent material has little effect, soil acidity being the more important factor.

There is no doubt that the incidence of whiptail has increased during and since the second world war. Old pasture was ploughed up for the planting of vegetables and if liming was omitted or imperfectly carried out, the deficiency frequently occurred. Investigation of soil conditions causing whiptail in the field can often be complicated by the fact that the soils are generally acid and plants may be affected by other injurious acidity factors, notably excess of manganese and aluminium. This is shown very clearly in the work carried out by Plant [50] who frequently found manganese toxicity and Whiptail occurring together.

Vegetable crops which are most commonly affected by the disorder are cauliflowers broccoli, lettuce and peas. Symptoms of the deficiency have been described by Hewitt and Jones [27 and 28] in a large number of crop plants and need no further mention here.

Plant [50] found that low levels of molybdenum in the leaf are associated with the occurrence of whiptail which, as previously found by Hewitt, Agarwala and Jones [29], is also characterized by nitrate accumulation and low ascorbic acid in the leaf. These criteria may possibly serve to distinguish between Whiptail induced by molybdenum deficiency and "pseudo-whiptail" caused by the environmental checks described by Wiebosch, Van Koot and Van't Sant [59].

Most varieties of summer and winter cauliflower seem to be affected by the disorder although Neenan and Goodman [39] found that the variety of cauliflower "All-the-Year-Round" was unaffected whereas the Cambridge varieties Nos. 6 and 7 were severely affected.

The minimum requirement for an average crop of broccoli or cauliflower is approximately 5-10 g of molybdenum per acre and this can be supplied by ½ oz of sodium molybdate. Plant [50] has found that a level of 0.05 p.p.m. Mo in broccoli leaves is critical and that healthy plants contain from 0.12-6.0 p.p.m. Drought accentuates the deficiency symptoms, and in a dry summer it was found that greater responses to molybdenum were obtained.

The practical control for whiptail is liming but if the soil is nearly neutral, a high-volume spray containing 200 p.p.m. Mo at the rate of 100 gal per acre or 2-4 lb per acre of sodium or ammonium molybdate, applied at an early stage of development may be used and is just as effective for most vegetable crops. The seedbed treatment also gives a good control of whiptail and this entails applying 1 oz of sodium molybdate in 10 gal water to 10 sq. yd of seedbed two weeks before planting. This ensures that the plants will contain sufficient molybdenum for their growth after transplanting. In Australia and New Zealand, molybdenized superphosphate containing 0.06 per cent MoO_3 is frequently used for correcting the deficiency, and is also used for establishing swards on molybdenum deficient soils.

Molybdenum Deficiency in Grassland

Judging from present evidence, molybdenum deficiency in grassland is invariably associated with the establishment and growth of clover. Practically all the molybdenum which is taken up by legumes is required for the nitrogen-fixing mechanism, and it is in the nodules that the element accumulates. A deficiency of the element decreases the nitrogen content of the clover, lowers pasture productivity and thus affects both the quality of the pasture as stockfeed and its value for increasing soil fertility. Large pink nodules on clover are a symptom of active nitrogen fixation whereas very numerous, small, pale nodules are characteristic of molybdenum deficient clover [3]. Oertel, Prescott and Stephens [42] have suggested that, on some acid soils, one of the major benefits of lime for legumes is to increase the availability of soil molybdenum.

Over large areas in New Zealand and Australia [2] molybdenum has been found to be a limiting factor for the establishment and growth of pasture, and very striking responses have been obtained through the use of sodium molybdate in those countries.

The same results have not been obtained in this country and there is no evidence to suggest that we have such molybdenum deficient soils. Most of our enclosed land has received lime and phosphate at some

period. When land is being ploughed up for reseeding it is customary to lime and apply phosphate. Permanent grasslands have generally received top dressings of basic slag which, in addition to phosphate, supplies small quantities of molybdenum. The soils most likely to be deficient in available molybdenum are those of the unreclaimed acid uplands, particularly the highly-leached podsolic soils of low pH, low phosphate and high iron content. Generally when these are being reclaimed they are limed and receive liberal dressings of phosphate in the form of slag, and usually good takes of grasses and clover are obtained.

The striking results obtained in New Zealand and Australia stimulated interest in the possibility that molybdenum might be a limiting factor in grassland production on reclaimed hill lands. A trial was laid down by the writer [61] in 1952 on a pasture which had been seeded down in 1944 and had subsequently received no lime or manurial treatment. Molybdenum was shown to be of significant value in increasing the yield of dry matter in 1952 and 1953 when only phosphate was applied, but without phosphate the molybdenum response was reduced to approximately one half.

When lime was present, however, the response to molybdenum with phosphate was small in the first year and did not show any effect in the second year.

Excess Molybdenum in Grassland

It has been mentioned earlier that both phosphate and lime increase the availability of soil molybdenum. Workers in England and Eire [23 and 57] have shown that the nutritional disorder in cattle caused by excess of molybdenum in herbage was accentuated by the use of basic slag. The molybdenum content of the herbage was always higher on pastures which had received heavy dressings of basic slag. On the other hand, it has been shown by Stout *et al.* [54] that sulphates, nitrogenous fertilizers and nitrate of potash decrease the availability of soil molybdenum.

The soils derived directly from Lower Lias clay contain a high proportion of molybdenum and calcium carbonate, are alkaline in reaction and are likely to give rise to teart pastures. On these soils it is practically impossible to prevent or reduce teartness and the use of short leys containing very little clover is advocated. On no account should lime or basic slag be applied.

Some soils which are derived indirectly from lias by drift or alluvial deposition may be acid in the surface and would not therefore be teart but could become so through liming. On these pastures, and those on alkaline limestone-derived soils of satisfactory phosphate status in Eire, which contain moderately high quantities of molybdenum in the herbage, prevention or reduction in teartness can be brought about by a careful system of management.

Practical Conclusions

To prevent the borderline types of teart pastures mentioned above from becoming Mo-toxic to animals it is of considerable importance that ordinary farming treatments such as liming, the use of basic slag and the development of clover rich swards should be discouraged and nitrogenous manuring should be encouraged.

Molybdenum deficiency in vegetable crops is found on acid or imperfectly limed soils and liming is still the most satisfactory method of reducing the incidence of the deficiency. Broccoli and cauliflower can, however, be grown successfully on moderately acid soils after soil or spray treatment with sodium molybdate at an early stage of the plant's development. Late sprays are ineffective. Watering the seed bed with a solution of sodium molybdate has also given a good control of whiptail.

It is apparent from the work of Mulder in the Netherlands that three very important soil factors are very closely associated with the problem of molybdenum deficiency on grassland, namely high acidity, phosphate deficiency and high iron content which appears to reduce molybdenum availability by strong absorption. It is also possible that on some acid soils in this country, lower dressings of lime, appropriately supplemented by a suitable quantity of molybdenum could be substituted for the very heavy dressings of lime normally recommended. If this were so, it would entail a considerable saving in transport and labour, since much of this hill land is not easily accessible to modern spreading machinery. The result of the experiment carried out on a reclaimed upland pasture in Wales, suggests that molybdenum top dressing could play an important role in the maintenance of similar types of pasture which have, at the time of reseeding, received liberal dressings of lime and phosphate.

References

1. S. C. Agarwala. *Nature*, 1952, **169**, 1099.
2. A. J. Anderson. *J. Australian Inst. Agr. Sci.*, 1942, **8**, 73-5.
3. A. J. Anderson. *Soil Sci.*, 1956, **81**, 173-82.
4. A. J. Anderson and A. C. Oertel. *Australia Council Sci. Ind. Research Bull.*, 1946, **198** (pt. 2), 25-44.
5. D. I. Arnon and P. R. Stout. *Plant Physiol.*, 1939, **14**, 599-602.
6. I. Barshad. *I. Soil Sci.*, 1951, **71**, 297-313.
7. I. Barshad. *II Soil Sci.*, 1951, **71**, 387-98.
8. H. Bortels. *Arch. Mikrobiol.*, 1930, **1**, 333-42.
9. H. Bortels. *Arch. Mikrobiol.*, 1937, **8**, 13-26.
10. L. B. Bull. *Proc. British Commonwealth Sci. Office Conf. Spec. Conf. Agr., Australia* 1949, 1951, 300-10.
11. E. E. Clayton. *N.Y. State Agr. Expt. St. Bull.*, 1924, 506.
12. I. J. Cunningham. *New Zealand J. Agr.*, 1955, **90**, 196-202.
13. E. B. Davies. *Nature*, 1945, **156**, 392.
14. E. B. Davies, G. A. Holmes and P. B. Lynch. *New Zealand J. Agr.*, 1951, **83**, 247-50.
15. E. B. Davies. 1952. *Proc. 14th Conf. New Zealand Grassland Assn.*, 1952, 182-91.
16. E. C. De Renzo, *et al. J. Am. Chem. Soc.*, 1953, **75**, 753.

17. A. T. Dick. *Australian Vet. J.*, 1953, **29,** 233-9.
18. A. T. Dick and L. B. Bull. *Australian Vet. J.*, 1945, **21,** 70-2.
19. C. M. Donald, B. I. Passey and R. J. Swaby. *Australian J. Agr. Research* 3, 1952, 305-25.
20. T. C. Dunne and L. T. Jones. *J. Dept. Agr. W. Australia*, 1948, **25,** 412-8.
21. H. J. Evans. *Soil Sci.*, 1956, **81,** 199-208.
22. W. A. Ferguson, A. H. Lewis and S. J. Watson. *Nature*, 1938, **141,** 553.
23. W. S. Ferguson, A. H. Lewis and S. J. Watson. *Jealott's Hill Research Sta. Imp. Chem. Ind. Ltd. Bull.* No. 1, 1940.
24. J. L. Grigg. *New Zealand Soil News No.* 3, 1953, 34-5.
25. J. L. Grigg. *New Zealand J. Sci. Technol.*, 1953, **34A,** 405-14.
26. E. J. Hewitt and D. G. Hallas. *Plant and Soil*, 1951, **3,** 366-408.
27. E. J. Hewitt and E. W. Jones. *J. Pomol. Hort. Sci.*, 1947, **23,** 254-62.
28. E. J. Hewitt and E. W. Jones. *Ann. Rept. Agr. and Hort. Research Sta., Long Ashton, Bristol.* 1948, 81-90.
29. E. J. Hewitt, S. C. Agarwala and E. W. Jones. *Nature*, 1950, **166,** 119-20.
30. C. M. Johnson, G. A. Pearson and P. R. Stout. *Plant and Soil*, 1952, **4,** 178-96.
31. J. O. Jones and W. Dermott. *Nature*, 1950, **165,** 248-9.
32. A. H. Lewis. *J. Agr. Sci.*, 1943, **33** II, 52-7.
33. W. R. Lobb. *New Zealand J. Agr.*, 1953, **87,** 3-11.
34. C. R. Millikan. *J. Australian Inst. Agr. Sci.*, 1947, **13,** 181-6.
35. K. J. Mitchell. *New Zealand J. Sci. Technol.*, 1945, **27A,** 287-93.
36. E. G. Mulder. *Plant and Soil*, 1948, **1,** 94-119.
37. E. G. Mulder. *Proc. Soil Soc. Florida*, 1950, **10,** 190-202.
38. E. G. Mulder. *Plant and Soil*, 1954, **5,** 368-415.
39. M. Neenan and O. G. Goodman. *Nature*, 1954, **174,** 192.
40. D. J. D. Nicholas and A. H. Fielding. *J. Hort. Sci.*, 1951, **26,** 125-47.
41. D. J. D. Nicholas and A. Nason. *J. Biol. Chem.*, 1954, II, **207,** 353-60.
42. A. C. Oertel, J. A. Prescott and C. S. Stephens. *Australian J. Sci.*, 1946, **9,** 27-8.
43. C. S. Piper. *J. Australian Inst. Agr. Sci.*, 1940, **6,** 162-4.
44. C. S. Piper and R. S. Beckwith. *J. Soc. Chem. Ind.*, 1948, **67,** 374-8.
45. C. S. Piper and R. S. Beckwith. *Proc. Specialist Conf. in Agr., Australia* 1949, 1951, 144-55.
46. W. Plant. *Agriculture* (*Lond.*), 1950, **57,** 130-4.
47. W. Plant. *Trans. 4th Intern. Congr. Soil Sci.*, 1950, **2,** 148-51.
48. W. Plant. *Nature*, 1950, **165,** 533-4.
49. W. Plant. *J. Hort. Sci.*, 1951, **26,** 109-17.
50. W. Plant. *J. Hort. Sci.*, 1956, **31,** 163-76.
51. W. O. Robinson, *et al. Soil Sci.*, 1951, **72,** 267-74.
52. W. O. Robinson and L. T. Alexander. *Soil Sci.*, 1953, **75,** 287-91.
53. P. R. Stout and C. M. Johnson. *Soil Sci.*, 1956, **81,** 183-90.
54. P. R. Stout, *et al.* 1. *Plant and Soil*, I, 1951, **3,** 51-87.
55. C. R. von Stieglitz and F. Chippendale. 1955. Nutritional Disorders of Plants, *Queensland. Dept. of Agric. and Stock*, Brisbane.
56. R. B. Walker. *Soil Sci.*, 1956, **81,** 191-7.
57. T. Walsh, M. Neenan and L. B. O'Moore. *Eire Dept. Agri. J.*, 1952, **48,** 32-43.
58. N. Wells. II. *New Zealand J. Sci. Technol*, 1956, II **37A,** 482-502.
59. W. A. Wiebosh, I. J. van Koot and Van't. Sant 1950. *Publ. Croefsta. voor Groenten en Fruit under Glass* 26.
60. C. H. Williams. *J. Sci. Food Agr.*, 1955, **6,** 104-10.
61. J. H. Williams. *Plant and Soil*, 1956, **7,** 327-40.
62. K. N. Wynne and G. L. McClymont. *Nature*, 1955, **175,** 471-2.

Entomology

Some Recent Work on Stem Eelworm *(Ditylenchus dipsaci)*

Stem eelworm is already well known as a most important pest of many crops and the range of its activities appears to be steadily widening. This is probably partly due to increasing attention which is being given to eelworm problems, though it is also possible that stem eelworm is by no means a static organism and may well develop new habits. Whatever the explanation, the fact remains that new hosts are found from time to time.

One of the most important findings in recent years is that of the lucerne race of stem eelworm in this country. A summary of the present position regarding this pest has been written by Brown [1]. Although lucerne has been cultivated for two hundred years in this country, until recently it has been remarkably free from pests. The first field of lucerne infested with stem eelworm was found in Essex in 1948. Other races of stem eelworm, such as the oat race or the clover race, are familiar troubles but they do not attack lucerne, whose own particular race of stem eelworm will only attack lucerne, alsike clover and sweet clover.

Nearly half the lucerne grown in this country is in the eastern counties, and the number of infestations have been highest there, although it has been found in many other parts of Great Britain. The earliest outbreaks were in fields grown from Hungarian seed, but since then French varieties such as Du Puits, Chartainvilliers and Ile de France have been most susceptible. The variety Provence seems to be less affected. In some fields, eelworm could readily be explained as a result of infection from other attacked fields nearby, usually as a result of lucerne being carried from one field across another. Soil infection or eelworm-carrying weed hosts, could bridge over the period between one infested crop and the next sowing of lucerne. In some fields, however, the evidence all pointed to seed-borne infestation of eelworms, where the first affected patches are small and scattered.

Symptoms of attack do not usually appear in the crop until the spring of the year following drilling, at which time small bare patches of about a yard in diameter may be found, with stunted and swollen plants round the edges. The subsequent increase in the field depends on many factors, the more important being surface drainage water and the spreading of infested lucerne about the field during harvesting operations. Often an infested crop will have to be ploughed up after only two or three years.

Stem eelworm has the power to remain alive in a desiccated condition for long periods. The eelworms eventually attack the flower heads and become attached to the seed coat. Many small pieces of infested leaves and stems are mixed with the seed during threshing and stem eelworms have now been found in lucerne seed, though, as expected, the numbers are not great. Other non-parasitic eelworms are often quite plentiful, so that expert identification is necessary. Stem eelworm is known to occur in France which is the source of most of our seed.

Prevention

At a time when lucerne is becoming increasingly popular as a crop, the introduction of such a dangerous pest as stem eelworm assumes great importance. Everything possible should be done to prevent or reduce such introductions. The small pieces of eelworm-infested debris found mixed with seed can to some extent be removed by thorough cleaning, but this alone can never get rid of all the eelworms. Fumigation of seed by means of methyl bromide has been found to be effective in freeing onion and clover seed, and more recent work has shown that lucerne seed will also stand this treatment well.

In 1945, Dr. T. Goodey [2] wrote that if all onion seed were fumigated, then an important source of infestation would be eliminated. The same could also apply to red clover. As the lucerne race of stem eelworm is not yet well established in this country, such fumigation would be correspondingly more valuable, and, coupled with efforts to prevent the eelworm spreading from fields already infested to those drilled with fumigated seed, this eelworm might even be eliminated from the country.

Infestation of Beet and Mangold Seedlings

In other directions, stem eelworm is also making history. R. A. Dunning [3] has described the first cases where stem eelworm has caused damage to seedling beet and mangolds in the field in 1953, since when he has pursued the matter further. Stem eelworm has been known for some time to attack beet and mangold, producing a crown canker in the autumn, but until recently no damage was ever seen at the seedling stage.

Infestation of the seedlings caused a bloating and falling of the leaf mid-ribs and petioles, the leaves being thickened and distorted. The growing point may also be invaded and become stunted and malformed. Fresh growing points develop in the axils and so lead to a multiple crown, or "many-neck", condition. During the summer, single and "many-neck" plants may produce quite healthy growth. The race of stem eelworm causing the symptoms in the seedlings, and also the crown canker in the autumn, is the common oat race which attacks oats, rye, onions, etc. Attacks on beet have been found to follow attacks by stem eelworm on oats, onions, or beet in previous years in the same field, but sometimes the source of infestation was not clear. Instead of the patchiness so characteristic of stem eelworm attacks, the infested beet were to be found scattered about the field among apparently healthy plants. Experiments have shown that beet are not very susceptible to eelworm attack, mangolds being more susceptible than beet. Although attacks on beet are rarely severe, they are widespread. Stem eelworm has been found to be carried on beet seed, but this is of little practical importance and the percentage of infested seedling resulting from sowing such infested seed is very low.

In the past, the crown canker which appears in the autumn was thought to be the result of invasion of the root at soil level in summer and early autumn, but this more recent work shows that infestation of the seedlings

in the spring leads to an infestation of the region of the leaf scars; this is the most probable means of invasion of the eelworms causing the crown canker. However, the exact relationship between spring and autumn infestation is still not clear. The rate of development of the canker, after the invasion of the eelworms, varies considerably.

Attacks of stem eelworm on beet in England have seldom caused economic loss, though it is a serious pest in Switzerland. For this reason the importance of beet and mangolds as hosts of stem eelworm should not be underestimated.

References

1. The occurrence of Lucerne Stem Eelworm in Great Britain with special reference to the origin of the attacks. F. B. BROWN, *Seed Trade Review*, 1957, **9**, 30-4.
2. *A. dip.* on onion seed and its control by fumigation with methyl bromide. T. GOODEY, *J. Helminth.*, 1943, **21** (1), 22-30.
3. Beet Stem Eelworm, R. DUNNING, *Nematologia*, 1956, I, **3**, 189-91.

L.N.S.

Farm Management

Success Factors in Milk Production

Results of investigations into the economics of milk production illustrate the great variations in costs and profitability from farm to farm. Many factors are responsible for these variations—quality of land, climate, incidence of disease, yields and seasonality of production, and so on. But the main factor affecting profits in dairy farming—as with other farming enterprises—is the standard of management on the farm. Variations in management make it impossible to establish what, in all circumstances, would be the most profitable system of dairying. Some high cost herds are profitable; but so also are some low cost ones. Similarly, good profits may be made both from high- and low-yielding herds. Conversely, both high and low cost herds may be unprofitable, as also may be both high and low yield herds. These apparent contradictions present a challenge to the farm management adviser. In answering that challenge, he must take account of the fact that milk production can be profitable under widely varying farming systems provided that the management of the dairy herd is adapted to the circumstances of the individual farm.

Range in Costs and Profit Margins

Results of an economic survey of milk production in Yorkshire in 1955-6 [1] show an average production cost per cow of £102 (2s. 7d. per gal) and a profit margin of £28 per cow (8½d. per gal). The range in costs, however, was from less than £60 per cow to over £140, and the profit margins ranged from a loss to over £68 per cow. On the whole, profit margins from small herds were lower than from large herds, because of

lower yields, higher labour inputs and a greater consumption of concentrates per cow. Out of 21 herds with under 20 cows, 15 had profit margins of less than £20 per cow. However, since the manual labour of the farmer was charged as an item of cost, the net income earned would be greater than the cost figures suggest. On the other hand, four of the herds of under 20 cows showed profit margins of over £25 per cow, and one achieved the exceptionally high figure of £69 per cow. These good results which appeared to be achieved by obtaining good yields of milk without extravagant cake feeding and keeping other costs low, particularly replacement costs, illustrate what can be done if advantage is taken of the opportunities for greater profit that exist on most farms.

Although the high-yielding herds were generally the more profitable, there were instances of high yields being obtained regardless of the level of costs incurred, and consequently, such herds showed little or no profit. Whereas for six herds with an average yield of 855 gallons a negative profit margin was shown, the costs per cow being as high as £142, a group of eleven herds with an average yield of only 675 gallons showed a profit margin of £27 per cow. On the other hand, seven herds with the high average yield of 1,029 gal per cow incurred costs of only £105 per cow, and subsequently obtained a profit margin of £65 per cow. In other words, high yields were profitable provided the use of feedingstuffs and other items of cost were not extravagant. Furthermore, relatively low yields could be profitable if the costs were kept at a correspondingly low level. These results underline the necessity of bearing in mind the objectives of the dairy farmer before advising him upon the best and most profitable system of feeding and management for his particular circumstances.

LABOUR COSTS

The three main inputs affecting the level of profits from milk production are labour, feeding and herd replacement policy. In this study labour inputs were often high for small herds—due in some instances to a lack of alternative work for the labourer. But even for large herds, the labour inputs were frequently excessive, and a closer study of work routines would pay ample dividends on many dairy farms.

FEED COSTS

There are so many possible variations in the types of home-grown foods fed to cows that it is difficult to demonstrate directly the influence of any particular type of feed. Amongst the most profitable herds it was found that about three-quarters were feeding either kale or silage or both. In general, profits were highest on the farms feeding both kale and silage to their cows during the winter, followed by those feeding kale and hay and then those feeding silage but no kale. There were, however, farms making good profits without using either kale or silage. Kale grazed during winter was a much cheaper food than when it had to be cut and carted; it is probably the cheapest food that is available during

the early winter months. Expenditure on purchased foods had a big influence on the profit made by the dairy herd. For herds yielding less than 700 gal per cow, the highest profits were secured if concentrate feeding did not exceed an average of 3 lb per gal over the whole year. For the herds yielding between 700 and 900 gal, all but one of the more profitable herds were fed at an average rate of less than 4 lb per gal, and most were receiving over the year less than 3½ lb per gal. On the other hand, with yields of over 900 gal per cow, good profits were secured by the herds fed on over 4 lb of concentrates per gal, as well as by several herds at much lower levels of concentrate feeding.

One conclusion drawn from the survey is that excessive levels of concentrate feeding were often directly responsible for low profits. While potentially good cows may respond to higher feeding rates and give more milk as a result, it is obvious that many of the cows in the lower-yielding herds were being fed at rates above their productive capacity or without the high level of cowmanship necessary to produce high yields. In addition, it is noted that some of the highest-yielding herds were receiving comparatively little purchased cake. The possibilities of substituting high quality grass in summer and high quality silage and kale in winter for part of the concentrate ration did not appear to be sufficiently appreciated. Even in the one case where above-average profit was secured with apparently high cake feeding, special conditions applied. This herd had low costs in other directions and produced a high proportion of winter milk so that returns were also above average; in this case the high level of concentrate feeding appeared to be justified by the results.

In view of the importance of feeding practices in dairying, the Agricultural Economics Department at Wye College has produced "A Guide to the Feed Economy of the Dairy Farm" [2]. This is a simple worksheet for checking that the feed economy of a dairy farm is sound. Every farmer should have at his fingertips material needed to fill in the worksheet, for modern farming cannot be conducted successfully without records. The leaflet is free and can be confidently recommended to farmers who wish to make sure that farm profits are not being reduced by incorrect feeding practices.

Herd Replacement Policies

Herd replacement policies usually depend largely upon rearing heifers for the future dairy herd. Out of a total of 43 costed herds in the Yorkshire study, no less than 40 were rearing heifers to bring into the herd, although only 34 actually transferred downcalving heifers into their dairy herds during the year. It was found that there were extremely wide variations in the costs actually incurred (from herd averages of less than £60 to over £100 per heifer) and in the ages at which the heifers calved (from herd averages of 2¼ years to over 3 years). There was no evidence from the costings data that the early calving heifers had received more expensive treatment than those calving later; on the whole the heifers that calved at an early age cost the least to rear, but there were great differences between farms.

Does it Pay to Rear Followers?

The high cost of rearing heifers raised the question of whether rearing was an economic proposition, particularly on smaller farms. It was found that to rear sufficient followers to supply one heifer per year to the herd required approximately 4 acres of land. In effect, therefore, for a farm where the cost of rearing heifers is about the same as the cost of purchasing similar heifers, 4 acres of land will be contributing nothing to the farm profit for each heifer per year brought into the dairy herd. For rearing to be an economic proposition, the rearing costs must be sufficiently below the cost of buying replacements to compensate for the loss of profit on the land used by the heifers. If a farm is producing a profit of £10 per acre, the rearing costs of a downcalving heifer should be £40 less than the purchase price of a similar heifer before the use of the land can be justified on economic grounds, subject to the condition that any saving by not rearing heifers is a real saving. For instance, labour, buildings and equipment must be capable of being fully utilized in other profitable ways if their cost is to be saved. The actual increase in profit that it is possible to obtain by cutting out rearing depends upon the actual costs being incurred in rearing, the acreage involved and the alternative uses to which it can be put, and of course on the continued possibility of buying heifers of the quality that is required at an appropriate price. Many small-scale dairy farmers would be well advised to calculate a budget to see whether rearing heifers is the most profitable use of their farm resources.

References

1. A. J. Wynne and Edith M. Wright. *Milk Production in Yorkshire* 1955-56, Farmers' Report No. 135, Economics Section, Department of Agriculture, University of Leeds, June, 1957. 29 pp., price 4s.
2. *A Guide to the Feed Economy of the Dairy Farm.* Department of Agricultural Economics, Wye College. Free.

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Mycology

Cereal Powdery Mildew *(Erysiphe graminis)*

Cereal mildew is one of the commonest plant diseases in Britain because strains of the fungus attack each of the principal cereals, oats, wheat and barley and most of the grasses. Moore and Moore [1] have pointed out that mildew is usually severe when a mild winter is followed by a dry spring. This is not an infrequent weather sequence, but until recently, little attempt has been made to assess the damage caused by the disease, or to make a detailed study of the factors influencing its development.

E. T. Jones [2] has obtained figures for mildew losses in oats by comparing the yields in N.I.A.B. trials of susceptible and resistant varieties in years when mildew was slight with yields in years when it was severe. The yield of the S.84—a susceptible variety—is taken as 100 per cent in each year. In 1947 and 1948 when mildew in the crop was slight, the resistant variety 0/747/10/7 yielded 87.2 per cent and 99.8 per cent. However, in the years when mildew was severe—1949 and 1950—it yielded 133.5 per cent and 112 per cent respectively. Last [3 and 4] has estimated the loss of yield in Plumage Archer spring barley grown at Rothamsted in 1954 and 1955. He obtained a good control of the disease by spraying areas of the crop five times at fortnightly intervals with lime sulphur. In 1954, mildew in the sprayed areas in June was less than one quarter of that in the unsprayed crop. The yields per acre from the sprayed areas were 36.9 cwt for a March sowing and 36.1 cwt for an April sowing. Corresponding yields for the unsprayed areas were 32.1 and 28.1 cwt representing a loss of crop of 13 per cent and 22 per cent. Since lime sulphur spraying did not affect the yield of the mildew resistant variety Hasia II—in which little mildew was present—it may be safely concluded that the reduction in crop was due to mildew. Similar results were obtained the following year. Sprayed plots sown in March yielded 38.2 cwt per acre compared with 34.4 cwt per acre for unsprayed areas. For April sowings the yields per acre were 31 sprayed and 22.8 cwt unsprayed. These figures cannot be taken as typical for all susceptible crops in these seasons because artificially infected plants were introduced into the plots in mid-May. They do however indicate the potential loss likely if seasonal conditions favour the appearance of the disease in susceptible crops by this time. So far, no figures are available for wheat in this country, but in America Schaller [5], by comparison of resistant and susceptible varieties has estimated the loss in susceptible wheats at about 25 per cent.

Nitrogen increases Susceptibility

A number of workers have studied the effect of manurial treatment on the incidence of mildew, and it is fairly generally agreed that adding nitrogen to a crop increases its susceptibility. In New Zealand, Smith and Blair [6] found that nitrogen had this effect on wheat only if it caused an increase in growth of the crop. Last [7] found a similar connection between growth response and mildew susceptibility in pot experiments with winter wheat. Nitrogen deficient plants were extremely resistant to mildew infection. Thus, the addition of nitrogen to wheat increased the growth rate, but resulted in increased susceptibility to mildew some days later. This susceptibility rose to a maximum and then fell off, but could be increased again by the further application of nitrogen. In later experiments, Last [8] found that the effect of nitrogen on mildew susceptibility varied with the age of the wheat plant. If nitrogen was applied before the flag leaf emerged, susceptibility rose to a maximum and then declined. However, if nitrogen was given after the emergence of the flag

leaf, there was a steady increase in the amount of mildew and no peak was reached, although there was no further growth of host leaf. From this series of experiments Last concluded that mildew development in winter wheat was least favoured if nitrogen was given in January. On the other hand, if nitrogen was applied in April and May a three-fold increase of mildew resulted.

What is the Effect of Other Nutrients?

There is some divergence of opinion on the effect of the other major nutrients. Stack [9] and Trelease and Trelease [10] found that if potash was applied when there was a high nitrogen and phosphate level it caused a reduction in the severity of mildew attack. On the other hand, Grainger [11], growing oats on soils low in phosphate found that the addition of potash increased susceptibility to mildew but that phosphate reduced it. With wheat, Smith and Blair [6] discovered that when applications of phosphate caused an increase in growth this was followed by a rise in mildew. The studies made by Tapke [12] on barley mildew may provide an answer to these apparent contradictions. He suggested that mildew infection depends largely on the predisposition of the host plants to the disease and that this is affected by all the interacting factors influencing plant growth. Last [7] also concluded that the internal changes in the host plant were more important in determining mildew susceptibility than were the changes in the micro climate within the crop. He found with spring wheat that the more rapid the growth rate the greater the increase in mildew. In addition to fertilizer treatment temperature was an important factor in determining susceptibility, for ten times as many mildew pustules developed at 14–20°C than at 7°C.

There is little information on the effect of seed rates on the incidence of mildew and the available results are contradictory. With wheat, Smith and Blair [6] found that when 24 seeds were sown per foot of drill there was six times more mildew than when the seeding rate was dropped to the extremely sparse one of one seed per foot. Last [4], using the less extreme variations of 1½ and 2½ bushels per acre of barley could detect no variation in mildew due to seeding rate. Although it is frequently stated that mildew attacks are associated with dense crops, more precise experiments seem necessary to clarify this question.

Early-sown Spring Cereals advocated

Time of sowing is a factor of great practical importance affecting the incidence of mildew in spring cereals. Last [4] showed with Plumage Archer barley in 1953 and Atle wheat in 1954, that compared with an April sowing, sowing in February greatly reduced the amount of mildew in the crops from May onwards. In 1954 [3] and 1955 [4], he carried out further experiments with Plumage Archer barley in which he recorded the effects of mildew on yield of early and late sowings. Barley sown on 22nd March, 1954 yielded 32.1 cwt per acre and the loss due to mildew was 4.8 cwt per acre, but when sowing was delayed until 5th April, the

yield fell to 28.1 cwt per acre, 8 cwt per acre being lost through mildew. In 1955, mildew depressed the yields of both early and late sowings by 8 cwt per acre, but the percentage loss was much less in the sowing made on 30th March which yielded 38.2 cwt per acre as against 31.0 cwt per acre from the crop drilled on 28th April. This effect is probably due to the earlier sown crops having a longer period of growth before rising temperatures favour the development of mildew.

References

1. W. C. Moore and F. J. Moore. Cereal Diseases. *Bulletin* 129, Ministry of Agriculture, Fisheries and Food. H.M.S.O., 1950.
2. E. T. Jones, *J. nat. Inst. agric. Bot.*, 1955, VII, 385.
3. F. T. Last. Effect of Powdery Mildew on the Yield of Spring Sown Barley. *Plant Pathology*, 1955, **4**, 22-4.
4. F. T. Last. The effect of date of sowing on the incidence of powdery mildew on spring sown cereals. *Ann. appl. Biol*, 1957, **45**, 1-10.
5. C. W. Schaller. The effect of Mildew and Scald Infection on yield and quality of Barley. *Agron. J.*, 1951, **43**, 183-8.
6. H. C. Smith and I. D. Blair. Wheat Powdery Mildew Investigations. *Ann. appl. Biol.*, 1950, **37**, 570-83.
7. F. T. Last. Some effects of temperature and nitrogen supply on wheat powdery mildew. *Ann. appl. Biol.*, 1953, **40**, 312-22.
8. F. T. Last. The effect of time of application of nitrogenous fertilizer on powdery mildew of winter wheat. *Ann. appl. Biol.*, 1954, **41**, 381-92.
9. H. Stuch. On the influence of mildew infection on the haulm strength of cereals receiving different nutrient substances. *Rev. appl. Mycol.*, 1926, **19**, 108.
10. S. F. Trelease and H. M. Trelease. Susceptibility of wheat to mildew as influenced by salt nutrition. *Bull. Torrey bot. Cl.*, 1928, **55**, 41-67.
11. J. Grainger. The ecology of *Erysiphe graminis*. *Trans. Brit. Myc. Soc.*, 1947, **31**, 54-65.
12. V. T. F. Tapke. Further studies in Barley Mildew as influenced by environment. *Phytopathology*, 1953, **43**, 162-6.

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Croxall

Provincial Note

The Grubbing of Old Farm Orchards

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TO ANYONE who travels through the county the very high proportion of unsatisfactory farm orchards in Worcestershire is obvious. This is not a new state of affairs for R. C. Gaut said in 1934 "One of the depressing features of Worcestershire orchards (and also elsewhere) is the enormous number of second- and third-rate varieties which abound. The produce, grubby, scabby and mis-shapen, classed variously as cookers or dessert, comes on to the market and depresses the value of the better kinds; it does no good for itself and it reduce the values of the choicest kinds. How it is to come about it is difficult to see, but there must come a time when the 'pot-hamper' rubbish will be compulsorily excluded from the wholesale markets." Similar comments were made by William Crump in 1894, and William Pitt, who made a land-use survey for the Board of Agriculture in 1810, said very much the same about Worcestershire farm orchards.

There is no exact figure of the acreage of unsatisfactory farm orchards but it may well be at least 10,000 acres. Unfortunately, even the fruit census figures do not give any indication of how old and useless are many of the trees. By and large, the Worcestershire acreage of top fruit has been generally diminishing for many years, but in view of the post-war planting of top fruit it would have been advisable to eliminate many acres of trees of unsuitable varieties which could not be managed so as to produce good fruit. Many of the old orchards were sited on good land which could now be put to much greater and more profitable use.

The changes in the top fruit acreage in the county are as follows:

	Acres	Annual change of acreage
1949	25,932	
1950	25,891	− 41
1951	25,732	−159
1952	25,818	+ 86
1953	24,264	−554
1954	23,615	−649
1955	23,176	−439
1956	22,144	−1,032

Mixed Orchards with Poor Swards

It has become a custom in Worcestershire, over many years, for orchards to be gapped up whenever a tree died so that what was originally a vintage cider or perry orchard now includes other kinds of fruit.

Depending on the market price of fruit (and fruit trees!) the occupier gapped up with apples, pears, plums or damsons with a result that very mixed orchards came into existence, including trees of many different ages. Sometimes the trees were very closely planted making it difficult to pick what little fruit might be produced on the tops of the trees. Spraying is impracticable under such conditions and often the occupiers have no equipment or experience in fruit tree spraying. Very little, if any, manure, other than the droppings from stock, is applied to the orchards, furthermore it would be impossible to manure orchards having trees with such mixed requirements.

In 1950 and 1951 farmers were being urged to see that their holdings produced as much as possible, and naturally attention was focused on many old orchards because the tree population was low and the soil and other site conditions made the land very suitable for general farm cropping. Many farmers were interested in the clearing of orchards where the work was not too costly, and the soil and site were suitable for the general run of crops that might be found on most mixed farms in Worcestershire.

Some farmers attach importance to the value of the grazing in their old farm orchards, but a recent survey in the western part of the county showed that over 60 per cent of the orchards contained herbage consisting mainly of agrostis, with perennial ryegrass contributing up to 15 per cent; less than 2 per cent of the orchard swards in this survey were classed as first-grade pastures. Nineteen per cent were rated second grade and contained 15 per cent to 30 per cent of perennial ryegrass. It must be pointed out that these old orchards do give shelter to stock in summer or winter but the grass gets little or no attention. Tree growth is very slow.

Crops and Prices

There is some outlet for the fruit from these old farm orchards for cider (there are very few perry pears left) but apples from these mixed varieties only command a market price of £6 or £7 a ton compared with £12 or more for vintage cider varieties. The normal weight of fruit in the farm orchard is generally between 18 cwt and 22 cwt a year, whereas the crop from a well-managed cider orchard is likely to be 5 or 6 tons of fruit a year. The value of the general run of apples and other fruit from farm orchards is so low that the occupiers are not prepared to spend anything on the orchard, which in turn leads to further deterioration. It is interesting to see that in the Ministry's index of agricultural prices cider apples (which include farm orchard fruit) have increased at a lower rate than any other type of agricultural or horticultural crop listed in the period 1937 to 1955. One must also bear in mind that the weight of crop per acre is no higher now than it was twenty years ago, whereas properly managed fruit or farm crops have increased considerably in weight per acre since then.

With the exception of dessert apples and pears, large numbers of which

were planted in the years immediately following the last war, the following figures from the 1951 fruit census show the high proportion of old fruit trees in Worcestershire, in the various classes of top fruit.

Type of Fruit	Under seven years old		Over seven years old	
	Acres	Trees	Acres	Trees
Dessert apples	966	96,834	2,464	192,574
Cooking apples	161	8,957	4,435	230,283
Pears	351	53,134	859	92,966
Cider and Perry	93	3,930	2,964	87,219
Plums	1,216	139,538	7,680	1,000,348
Cherries	212	8,952	1,445	58,750
Other fruits and nuts	16	2,532	86	5,644

The 4th June returns show an interesting change in the percentage of orchards to arable land in Worcestershire and England and Wales:

	1950	*1951*	*1952*	*1953*	*1954*	*1955*	*1956*
Worcestershire	6.89	7.04	7.14	6.66	6.54	6.41	6.21
England & Wales	1.1	1.08	1.07	1.09	1.11	1.13	1.15

Orchard Clearance Grants

Very little progress was made with grubbing on any scale until the £12 per acre grant for ploughing-up exceptionally difficult old grassland was introduced in 1952. Although many of the orchard sites that were tackled cost over £40 an acre to clear, the grant was an inducement, and during 1952-3 grants on 135 applications relating to 600 acres of orchard were paid. Probably not more than 5 per cent of that area has since been replanted with fruit and the same applies to all orchards cleared since. Occupiers whose whole acreage is devoted to fruit are not eligible for any orchard clearance grants because their replacement of worn out trees is a routine job.

In September, 1953, the marginal production scheme grants were introduced, and derelict orchards became eligible for grant under this scheme as well. For this purpose, a derelict orchard meant one which had not been capable over the last four or five years of producing a crop worth marketing. At that time funds were limited so not all applicants could get the full 50 per cent grant. One expected complication, namely that tenancy agreements relating to fruit tree numbers being maintained would make it difficult for many tenants to obtain their landlord's consent to grub old orchards, did not arise. In practice it was found that landlords

were usually prepared to waive those parts of tenancy agreements which stipulated that tree numbers were to be kept up by replanting gaps. In a few cases matters were held up for a time but eventually agreement was reached.

Grubbing Campaign

To get the most easily cleared orchards on the best land free for general cropping, a tree grubbing campaign was started in 1952. Demonstrations of tree grubbing together with all the subsequent work involved, were arranged throughout the county using either A.E.C. equipment or in collaboration with contractors. In 1953, a film was made showing the grubbing and all subsequent operations, including the wheat crop which was successfully grown the same year. This film was shown at twenty evening meetings in the following winter and did much to encourage farmers to make use of the marginal production scheme and ploughing scheme grants. The county press gave full length write-ups with illustrations of these demonstrations. District and horticultural officers made what opportunities they could to discuss orchard clearance and alternative and more rewarding uses for which the site could be used.

Costs of grubbing obviously vary with the size and number of trees concerned. Plums—in spite of there being more trees per acre—are usually the cheapest to clear because by the time they are thirty or forty years old they are still not very large and have died back to a certain extent. Cherry and perry pears are the most difficult to deal with because the trees are usually of considerable size and are very well rooted. Frequently, the biggest specimens are blasted sufficiently to loosen them so that they can be pushed out without a great deal of further trouble. Most of the apple orchards are of tall standard trees which may be difficult to move, depending on the type of soil. Since some of the Worcestershire orchards were planted on heavy lias and keuper marl, the clearance costs on these sites are higher because of the great effort required to get the trees out of the soil and to carry out the later cleaning operations.

Eighteen months ago the average cost of clearing all types of orchards worked out at about £45 per acre. With grass orchards, the £12 per acre ploughing-up grant was deducted from the total cost per acre and a 50 per cent marginal production grant paid on the remainder plus, of course, the £12 grant. Arrangements were made to see that an exceptionally high grant was not paid where the clearance costs were substantially below the average. During the past year the average grants paid amounted to about 60 per cent of the cost of the work.

Arrangement of Work

It is most important to determine in advance the actual working programme to be followed, otherwise the site soon becomes cluttered up with saleable timber, tops for burning, tree butts and disturbed soil. The cheapest way is to push trees out as they stand and drag them

complete to the site of a fire, where the heads can be cut off and sawn into smaller pieces and the butts cut off. This leaves the top wood very handy for being moved on to the fire by specially made large tractor-mounted sweeps. Saleable timber is dragged clear and the butts stacked at a convenient spot nearby. Butt disposal is probably the biggest difficulty to overcome but often these have been pushed into disused pools and covered over with soil. An alternative method, not usually so satisfactory, is to bulldoze out a pit so that the stumps can be buried. If heaps of butts are left on the surface of the soil the earth does in time weather off and they can be burnt, but during the intervening years in the drying-out stage a pile of butts can provide shelter for rabbits.

Experience shows that it is not worthwhile for a farmer to use his normal farm equipment on the heavier orchard clearing work; it is preferable to employ contractors to do the clearance and initial ploughing, leaving the lighter operations for the farmer. Farmers soon realize that a stipulation in the marginal production scheme gives them no credit for their own personal labour on the job, or the use of their machinery and tackle beyond the fuel and oil consumed. The farm worker's time is of course eligible for grant. Clearance work goes on through most of the year, although obviously more is done in late winter and early spring which fits in quite conveniently with the call for labour on ordinary farm work, especially on heavy soil sites. If suitable tackle is used properly trees can be removed from the soil with very little disturbance of the earth, which means that later cultivations and crops are even. It was soon found out that the use of bulldozers with long blades or substantial amounts of explosives used in blasting, made excessively deep craters and brought much unwanted subsoil to the top. Consequently, the A.E.C. and contractors introduced small bulldozer blades which concentrated the power of the machine on to the tree butt and also gave some leverage higher up the trunk. The winching out of trees proved to be too slow and costly. The initial subsoiling and/or deep ploughing of a cleared site needs the heaviest tackle because of the roots which have to be moved. Special subsoilers have been developed for this work. Picking up the large roots is a tedious and costly process, but small roots and the smaller branches and shoots soon rot away if worked into the soil. They may cause some difficulty with harrows and drills in the first season, but after that they seem to be no trouble. Rotovating cleared sites has not proved to be worth while.

Costs

Examples of costs of work are as follows: $2\frac{3}{4}$ acres of orchard at Droitwich, 22 apple trees of about 18 in. diameter and 6 pears about 24 in. diameter were grubbed. The latter were blasted to ease them at approximately 10s. a tree. The complete cost for this grubbing was £16 15s. and the ploughing was carried out by the farmer with his own mounted plough. At Home Farm, Croome a contract was made to grub and clear trees, pre-disc the turf, plough and carry out all cultivations including drilling wheat.

There were about 450 apple and pear trees between 12 and 18 in. in diameter in this 9-acre orchard. Pushing down and de-rooting was carried out by an International TD.9 fitted with a small "home-made" bulldozer blade, whilst cutting up and clearing was done with a mounted circular saw and a specially made tractor mounted sweep for collecting and depositing the waste material on the fire. The price for the complete job from grubbing to drilling was £208 10s. for the 9 acres or £23 3s. per acre.

In an article in the Worcestershire Agricultural Journal, W. G. Hume quoted examples of work carried out in 1954, and said that taking 14 plum grubbing sites at random, representing 60 acres, the average cost per acre was £38, the jobs themselves ranging from £27 to £50 per acre. Most of the orchards contained a fairly close plant of 120 to 180 trees per acre and the variations in cost depended upon the density and size of the trees and the size of the plantation. It is much cheaper per acre to clear a large area than a small one and instances of this are shown in a few examples. Three 1-acre orchards cost respectively £40, £47 and £50; the average of three 5-acre orchards was £38 per acre, and in a 16-acre orchard the cost was £27 per acre.

In 1956-7 the average gross cost for clearing orchards was about £42 per acre. More difficult orchards are now being tackled, but improved equipment and working methods have enabled costs to be kept down in spite of rising prices.

The efforts which have been made in Worcestershire over the past five years to encourage orchard clearance seem to have had some results, but the success of the campaign has owed much to the grants which were made to farmers who carried out the work. In spite of some new planting there was, between 1952 and 1956, a reduction of 3,452 acres of top fruit, which was afterwards made available for farm or market garden crops.

After recording the condition and problems of neglected farm orchards, it would be wrong to leave an impression that this kind of fruit production is representative of fruit growing in Worcestershire. There are many thousands of acres of modern orchards whose management and production compare well with anywhere else in this country.

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